Strategic Plan for ITS Communications

Prepared for:

Arizona Department of Transportation
in cooperation with
U.S. Department of Transportation
Federal Highway Administration

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16. Abstract

This report presents the results of a study by Kimley-Horn and Associates, Inc. for Arizona Transportation Research Center to develop strategies for the State of Arizona to evolve/develop state-of-the-art communication infrastructure(s) to support Intelligent Transportation System(ITS) deployments to improve the overall level of safety and efficiency of Arizona's highway network.

The report reviews the ITS National Plan (3/95) and Arizona's ITS priorities as defined by the study Technical Advisory Committee. The report reviews existing and planned ITS-related systems within Arizona. The Freeway Management System(FMS) in the Phoenix area is a state -of-the-art system that includes video surveillance, incident detection, ramp metering, and many other functions. Future major systems being considered include an FMS in Tucson and a rural FMS in Flagstaff for the I-40 corridor.

The report recommends an evolution to open standards based communication infrastructure. The report discusses wireline modem technologies, the U.S. digital hierarchy, SONET fiber hierarchy, and multiplexing and EIA-232. A discussion of system level digital communication system design is presented and includes information on ITS data sources.

The report concludes with recommendations for statewide, metropolitan area, and rural area communication infrastructure(s) plus other considerations. The report concludes that open standards facilitate modular, expandable, and scaleable communication infrastructures to accommodate the evolutionary nature of ITS service definition(s), benefit validation(s), and deployment(s).

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
ft oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg

APPROXIMATE CONVERSIONS FROM SI UNITS

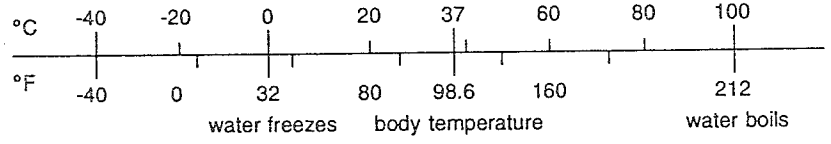
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
m^2	meters squared	1.19	square yards	yd^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.31	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T

TEMPERATURE (exact)

Symbol	When You Know	Do The Following	To Find	Symbol
°F	Fahrenheit temperature	°F - 32 ÷ 1.8	Celcius temperature	°C

TEMPERATURE (exact)

Symbol	When You Know	Do The Following	To Find	Symbol
°C	Celcius temperature	°C x 1.8 + 32	Fahrenheit temperature	°F



METER: a little longer than a yard (about 1.1 yards)
LITER: a little larger than a quart (about 1.06 quarts)
GRAM: a little more than the weight of a paper clip
MILLIMETER: diameter of a paper clip wire
KILOMETER: somewhat further than 1/2 mile (about 0.6 mile)

*SI is the symbol for the International System of Measurement

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EXECUTIVE SUMMARY

Arizona has established as a goal the deployment of Intelligent Transportation Systems (ITS) that will improve the safety and efficiency of the State's transportation infrastructure.

In "Assessment of ITS Benefits, Early Results" (dated August 1995 by Mitre under contract to FHWA), the benefits of ongoing early ITS-related programs were discussed as related to the goals stated in the National ITS Program Plan. Examples of the benefits identified include the Minnesota Department of Transportation's (MNDOT) freeway ramp meter system which increased capacity (from 1800 to 2200 vehicles per lane per hour), increased average speed (from 34 to 46 MPH), and reduced accident rates 27%. Another example is a London video surveillance system with speed enforcement cameras that have reduced speeds by approximately 10%, accidents by more than 20%, and serious injuries and fatalities by about 50%. Another example is an Oregon Commercial Vehicle Operation (CVO) electronic clearance program which enabled an increase of 90% in weighings and 428% in safety inspections between 1980 and 1989 with a staff increase of only 23%. Benefits are also projected for ITS programs that have not yet reached the data collection and evaluation phases. Although many existing programs provide many positive verifications, the exact nature and extent of ITS benefits are still being defined and evaluated in current and planned ITS projects.

The National ITS Program Plan identifies 7 user service bundles and 29 subordinate user services. Many ITS-related systems have been deployed. Future ITS deployments and operations will integrate these existing systems through federal, state, and local partnerships that will include public and private participation. The 5-year ITS deployment vision is an era of travel information and fleet management.

Arizona's ITS priorities have been identified as: 1) Metropolitan Advanced Travelers Management System (ATMS), 2) Rural Emergency Management, 3) Rural and Metropolitan Advanced Traveler Information System (ATIS), 4) CVO including North American Free Trade Agreement (NAFTA) border crossings, 5) integration of Freeway Management System (FMS), metropolitan FMS, and signal systems, and 6) integrated multiple Traffic Operations Center (TOC) requirements.

A modern communication infrastructure is required to support emerging and evolving ITS services. Existing ITS-related systems in Arizona include: 1) Phoenix Arizona Department of Transportation (ADOT) FMS, 2) many jurisdictional and some state-owned signal systems, 3) Weigh-in-Motion/Automatic Vehicle Count (WIM/AVC) stations along interstates, 4) ATR for recording traffic counts, 5) call boxes, and 6)

SCAN® automated weather stations. Future ITS plans include Freeway Management System's for Tucson and Flagstaff and integration of Maricopa County FMS with jurisdictional signal systems for regional ATMS/ATIS capabilities.

ADOT has limited existing communication facilities. ADOT has a state-wide Wide Area Network (WAN) interconnecting Local Area Networks (LANs) via 1.544 Mbps, DS-1 circuits. Reports indicate that this network is heavily loaded. ADOT has radio and microwave systems used for construction and maintenance. Based on recent Federal Communications Commission (FCC) rule changes, new vendor equipment, for certain Part 90 bands, must support more spectrally efficient modulation/channelization capabilities. This offers Arizona an excellent opportunity to obtain wireless communication capacity, essentially on normal upgrade schedules, provided a plan is in place.

The Phoenix FMS has an existing communication infrastructure; however, it uses a six year old architecture based on non-standard proprietary Frequency Division Multiplexing (FDM) techniques. A plan should be developed to accommodate upgrades to integrated ITS requirements. Fortunately, the expensive fiber cable plant should be usable and should accommodate more modern standards-based fiber terminals.

The recommended strategy for evolving to a standards-based communication architecture is based on the widely deployed T1 digital hierarchy and recently emerged Synchronous Optical Network (SONET) multiplexing standards. These standards, along with subrate multiplexing for lower speed EIA-232 or equivalent data rates, provides a modular, scalable, and expandable suite of data rates that is well supported by cost-effective products for private network implementation as well as compatible interfaces into commercial services. In addition, wire, wireless, and fiber media options may be employed, as advantageous, for most links. It should be noted that Single Mode Fiber Optics (SMFO) cable has reached cost parity with wire and offers significant advantages in terms of media bandwidth and repeaterless distances. Fiber terminals continue to be more expensive, but the cost difference is narrowing. Compatible wireless microwave equipment costs are also on a downward trend and are often cost competitive with wire and fiber depending on application and installation requirements.

It is recommended that ADOT develop a statewide communications infrastructure using fiber and appropriate SONET (OC-n) standard circuits. We strongly endorse the state's program for creating a private/public partnership to install a fiber infrastructure along the interstates and offer suggested technical goals to achieve in partnership negotiations. This private network should accommodate private long distance access to local telephone exchanges and provide cost-effective statewide access for voice, sensor, variable message sign (VMS), etc.

It is recommended that ADOT adopt the National Electrical Manufacturers Association (NEMA) National Transportation Control/ITS Communication Protocol (NTCIP) standard for controller communication links and an outreach/support program to help various state agencies and local jurisdictions understand and implement these links in a complementary manner.

1.0 INTRODUCTION

The state of Arizona has established the goal of deploying state-of-the-art systems that will improve the overall safety and efficiency of the state's transportation network. These goals are in concert with both state requirements and the national Intelligent Transportation System (ITS) program.

The national ITS program identifies a suite of recommended ITS services. State and local jurisdictions can select which ones to implement in support of local requirements. The national definition of these services will provide consistency so that data collected and/or distributed within a particular ITS service can be shared with other local, state, and national ITS agencies or services.

A transportation system must be distributed to support the geographical areas that require these services. ITS systems will have sensors, terminals, kiosks, variable message signs, controllers, Traffic Operations Centers (TOC), and many other devices distributed over the geographic area where transportation services are provided. To support the deployment of these services, a modern, cost-effective, communications infrastructure is required to collect, integrate, process, and distribute this ITS data.

It is the purpose of this report to identify communication technologies that are suitable for supporting the deployment of ITS services within Arizona and the key elements required in a strategic ITS Communication plan for the Arizona Department of Transportation (ADOT). This report is organized as follows:

2.0 ITS SERVICES

Evolution to a strategic ITS communications plan should consider:

- The National ITS Program Plan.
- Arizona ITS Requirements.

2.1 *THE NATIONAL ITS PROGRAM PLAN*

The National ITS Program Plan, First Edition, March 1995 consists of four (4) documents:

- An Executive Summary.
- A Synopsis.
- Volume I, Goals of ITS.
- Volume II, User Services.

ITS deployments and operations will unfold through federal, state, and local partnerships that will encourage private company participation to develop and market ITS products and services. The National Plan develops the framework to support this evolution. As such, the National Plan will:

- Promote shared ITS goals.
- Guide ITS investment decisions.
- Encourage coordination.
- Maintain a forum on deployment.
- Ensure ITS is Intermodal.

The National Plan currently identifies 7 User Service Bundles and 29 subordinate User Services that are presented in **Table 2.1-1**. Many systems have already been deployed (**Table 2.1-2** from National Plan) which include ITS functionalities that will be integrated, perhaps after upgrading, into future ITS deployments. The plan is actually a multiphased process that builds upon itself. It is based on participation and input from federal, state, and local government stakeholders, plus private stakeholders. It is based on currently defined requirements and visions; however, as it evolves and more experiences are acquired, the National Plan will be modified accordingly and subsequent editions published.

Table 2.1-1

ITS User Services and Bundles

Bundle	User Services	Arizona Priorities	
		Urban	Rural
1. Travel and Transportation Management	1. En-route Driver Information	✔	Some
	2. Route Guidance	✔	
	3. Traveler Services Information	✔	
	4. Traffic Control	✔	✔
	5. Incident Management	✔	✔
	6. Emissions Testing and Mitigation		
2. Travel Demand Management	7. Demand Management and Operations	✔	
	8. Pre-trip Travel Information	✔	✔
	9. Ride Matching and Reservation		
3. Public Transportation Operations	10. Public Transportation Management		
	11. En-route Transit Information	✔	
	12. Personalized Public Transit		
	13. Public Travel Security		
4. Electronic Payment	14. Electronic Payment Services (Tolls)	Hold	
5. Commercial Vehicle Operations	15. Commercial Vehicle Electronic Clearance		✔
	16. Automated Roadside Safety Inspection	✔	✔
	17. On-board Safety Monitoring	✔	
	18. Commercial Vehicle Administrative Processes		✔
	19. Hazardous Materials Incident Response	✔	✔
	20. Freight Mobility	✔	✔
6. Emergency Management	21. Emergency Notification and Personal Security	✔	✔
	22. Emergency Vehicle Management	✔	Some
7. Advanced Vehicle Control and Safety Systems	23. Longitudinal Collision Avoidance		
	24. Lateral Collision Avoidance		
	25. Intersection Collision Avoidance		
	26. Vision Enhancement for Crash Avoidance		
	27. Safety Readiness (Electronic Signs)	✔	✔
	28. Pre-crash Restraint Deployment		
	29. Automated Highway System		

Table 2.1-2

Examples of Current ITS Deployments

System	User Service(s) Provided	Status
Transportation Management ▸ *Los Angeles Automated Traffic Surveillance and Control* ▸ *Seattle Freeway Management System* ▸ *Phoenix Freeway Management System* ▸ *Las Vegas Area Computer Traffic System*	▸ Traffic Control ▸ Incident Management	▸ Islands of ATMS deployment ▸ Limited deployment of video cameras ▸ Manual monitoring ▸ Primarily public sector influence
Travel Information ▸ *MetroTraffic* ▸ *ShadowTraffic* In-vehicle Route Guidance ▸ *Oldsmobile Guidestar* PC-based Software ▸ *City Streets*	▸ Pre-trip Travel Information ▸ En-route Driver Information ▸ Route Guidance ▸ Traveler Information Services	▸ Radio and TV broadcasts in most markets ▸ Limited deployment of route guidance ▸ Primarily private sector influence
AVL/AVI ▸ *Various Transit Systems* ▸ *Various Commercial Vehicle Operators* ▸ *Various Emergency Management Services*	▸ Public Transportation Management ▸ Commercial Fleet Management ▸ Emergency Vehicle Management	▸ Limited AVL applications/ scheduling software ▸ Limited AVI deployment ▸ Public and private sector influence
Electronic Toll Collection ▸ *Illinois State Toll Highway Authority* ▸ *Oklahoma PIKEPASS*	▸ Electronic Payment Services	▸ Limited/isolated deployment ▸ Public and private sector influence
Electronic Clearance ▸ *HELP, Inc.* ▸ *Advantage I-75 (Operational Test)*	▸ Commercial Vehicle Electronic Clearance	▸ Limited/isolated deployment ▸ Public and private sector influence
Collision Avoidance Systems ▸ *VORAD/Greyhound Bus Lines*	▸ Longitudinal Collision Avoidance ▸ Lateral Collision Avoidance	▸ Limited/isolated deployment ▸ Primarily private sector influence

No firm schedules for deployment are presented; instead 5-, 10-, and 20-year deployment visions are presented:

- 5-year: Era of Travel Information and Fleet Management (**Figure 2.1-1**).
- 10-year: Era of Transportation Management (**Figure 2.1-2**).
- 20-year and beyond: Evolution of transportation data collection, dissemination, and traffic management. Evolution to the Automated Highway System (AHS).

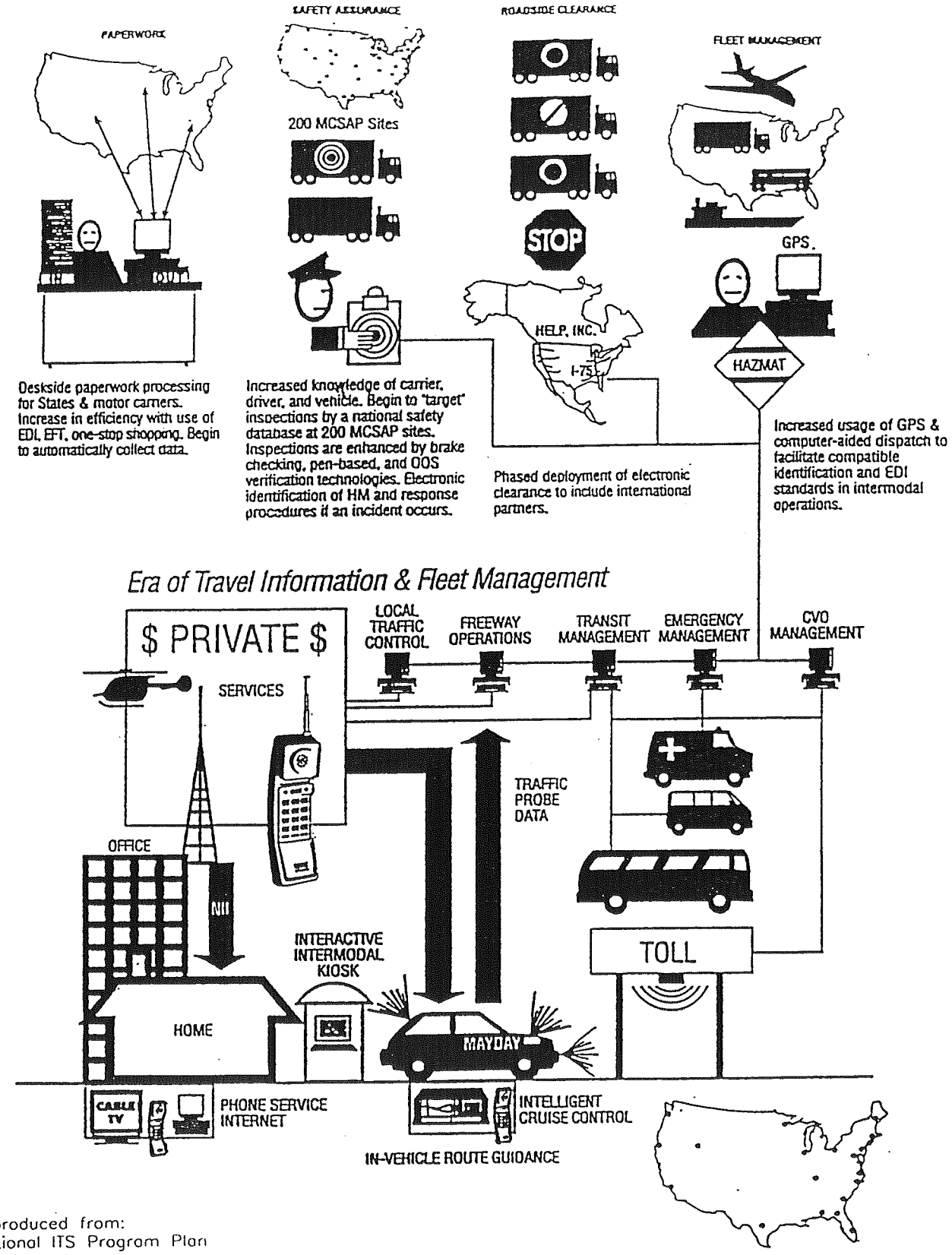
2.2 ARIZONA ITS REQUIREMENTS

Arizona is a state with widely divergent communities and communication infrastructures. As such, it will benefit greatly by implementing and integrating services. **Figure 2.2-1**, a map of the state, depicts major metropolitan areas, major freeways, major tourist attractions, significant CVO activity, and significant rural highways.

In terms of the National ITS Program Plan and based on guidance from the project Technical Advisory Committee, Arizona ITS requirement priorities are:

- Integrated metropolitan traffic control and incident management (ATMS).
- Rural and metropolitan Advanced Traveler Information Systems (ATIS).
- Rural emergency services.
- CVO services including significant border traffic across the Mexican border.
- Significant rural transit.
- A need to integrate existing FMS and signal systems into evolving ITS services.
- A communications and operations plan for location of TOCs for multiple ITS services.

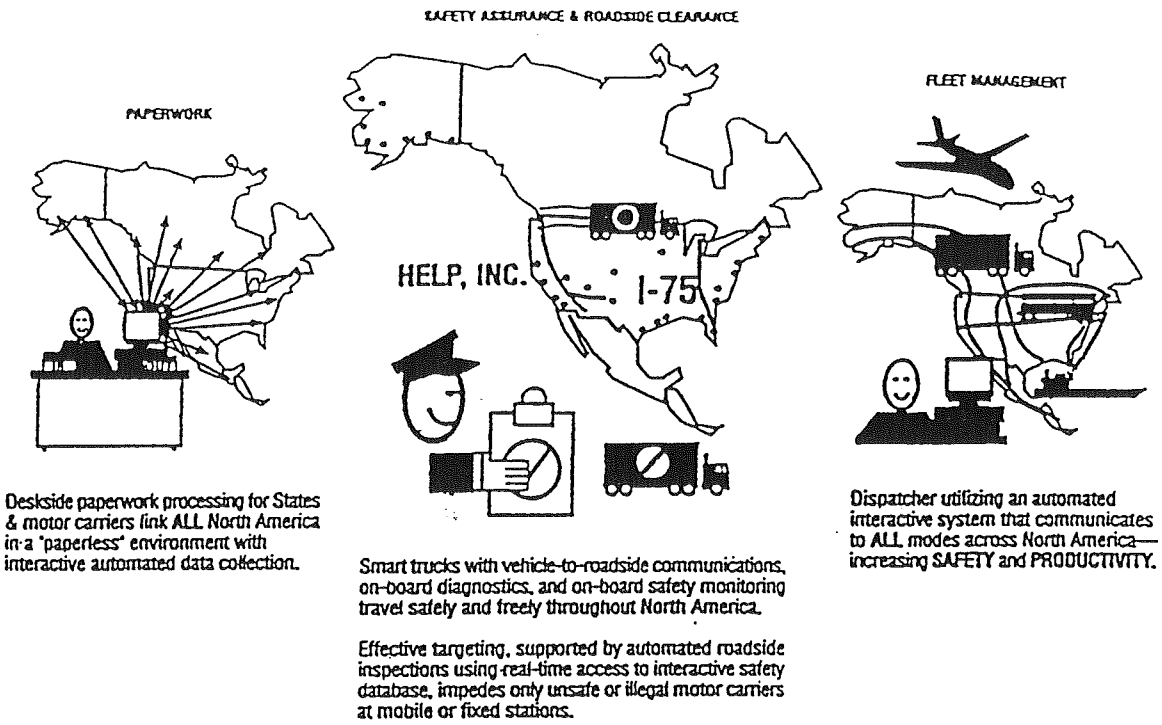
The two right hand columns in **Table 2.1-1** identify the specific ITS user services that the ADOT Technical Advisory Committee and KHA have jointly identified to address the above priorities.



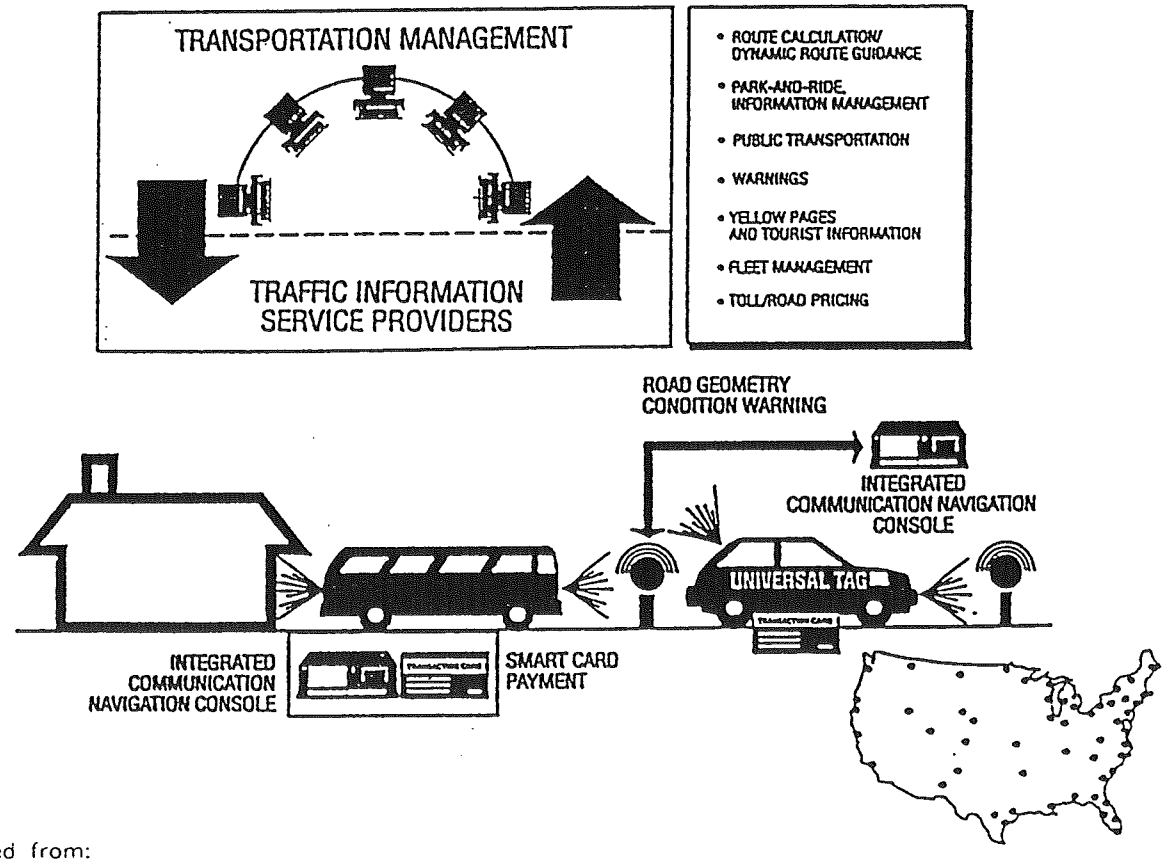
* Reproduced from:
National ITS Program Plan

5 - Year Deployment Vision

Figure 2.1–1



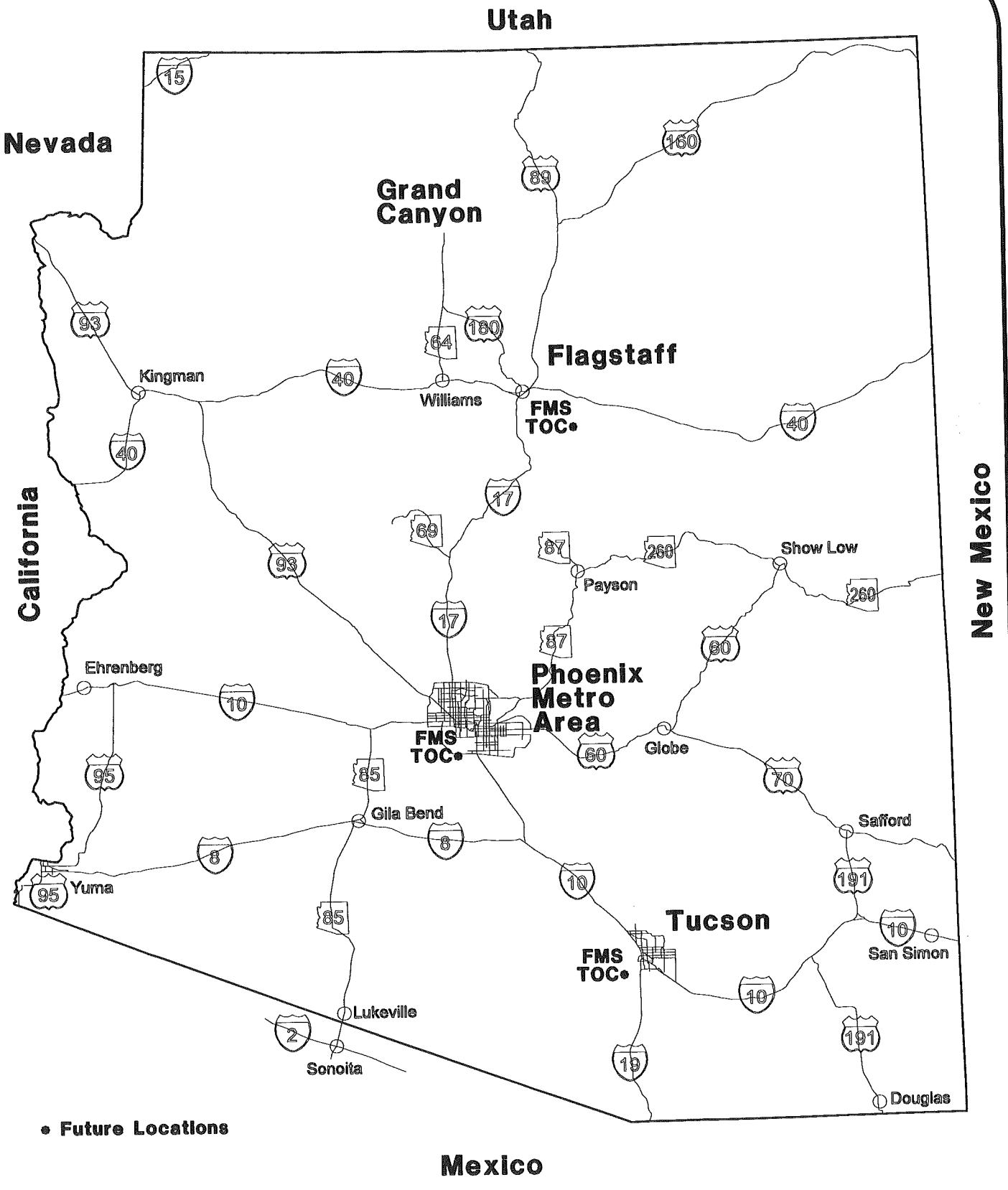
Era of Transportation Management



* Reproduced from:
National ITS Program Plan

10 - Year Deployment Vision

Figure 2.1-2



Significant Arizona ITS Requirements and Locations

Figure 2.2–1

3.0 EXISTING ADOT ITS-RELATED SERVICES

ADOT has already deployed equipment and systems that provide ITS-related functionality and that will require upgrades and/or enhancements to be part of a statewide integrated ITS system.

3.1 FMS SYSTEM - PHOENIX

ADOT is implementing a Freeway Management System (FMS) in the Phoenix metropolitan area. Currently, the system includes approximately 29 miles of freeway along I-10 and I-17. The system is designed to accommodate more than 200 miles of freeway in future expansion. It includes the following equipment:

- Loop detectors.
- Closed circuit television (CCTV) (approximately 1 mile spacing).
- Variable message signs.
- Ramp metering.
- Traffic interchange signals.
- Freeway drainage systems.
- Tunnel management system.

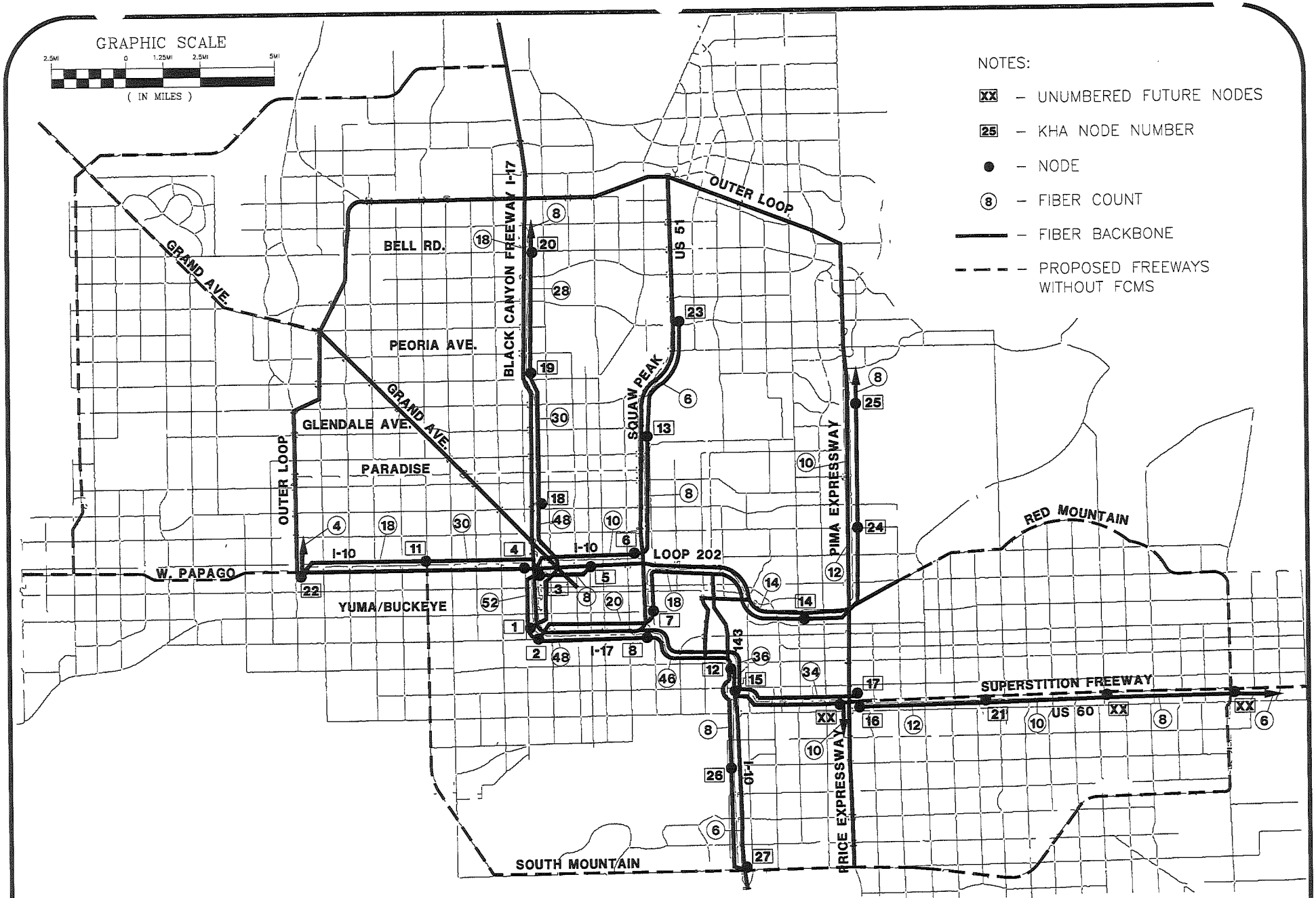
The field equipment communicates with the communications field nodes via fiber for the broadband video and via TWP for the low-speed data used by equipment controllers. Communication from the field nodes to the TOC is over fiber optic cable. A map of the freeway FMS is presented in **Figure 3.1-1**.

The TOC is equipped with:

- Operator workstations with both video and computer displays.
- A bank of video monitors to display field video.
- A video switch to route video to the appropriate monitor.
- A large screen graphic display for general status information.
- A Sun computer system.
- A communications subsystem that interfaces, controls, and manages field communication.

3.2 SIGNAL SYSTEMS

Arizona has numerous signal systems installed throughout the state. Most of the signal systems are owned and operated by local jurisdictions and are listed in **Table 3.2-1**. The state also owns and operates signal systems as listed in **Table 3.2-2**. **Figure 3.2-1** shows the location of signal systems in Arizona.



FMS Communication System
29 Miles Implemented, Over 200 Miles Planned

Figure 3.1–1

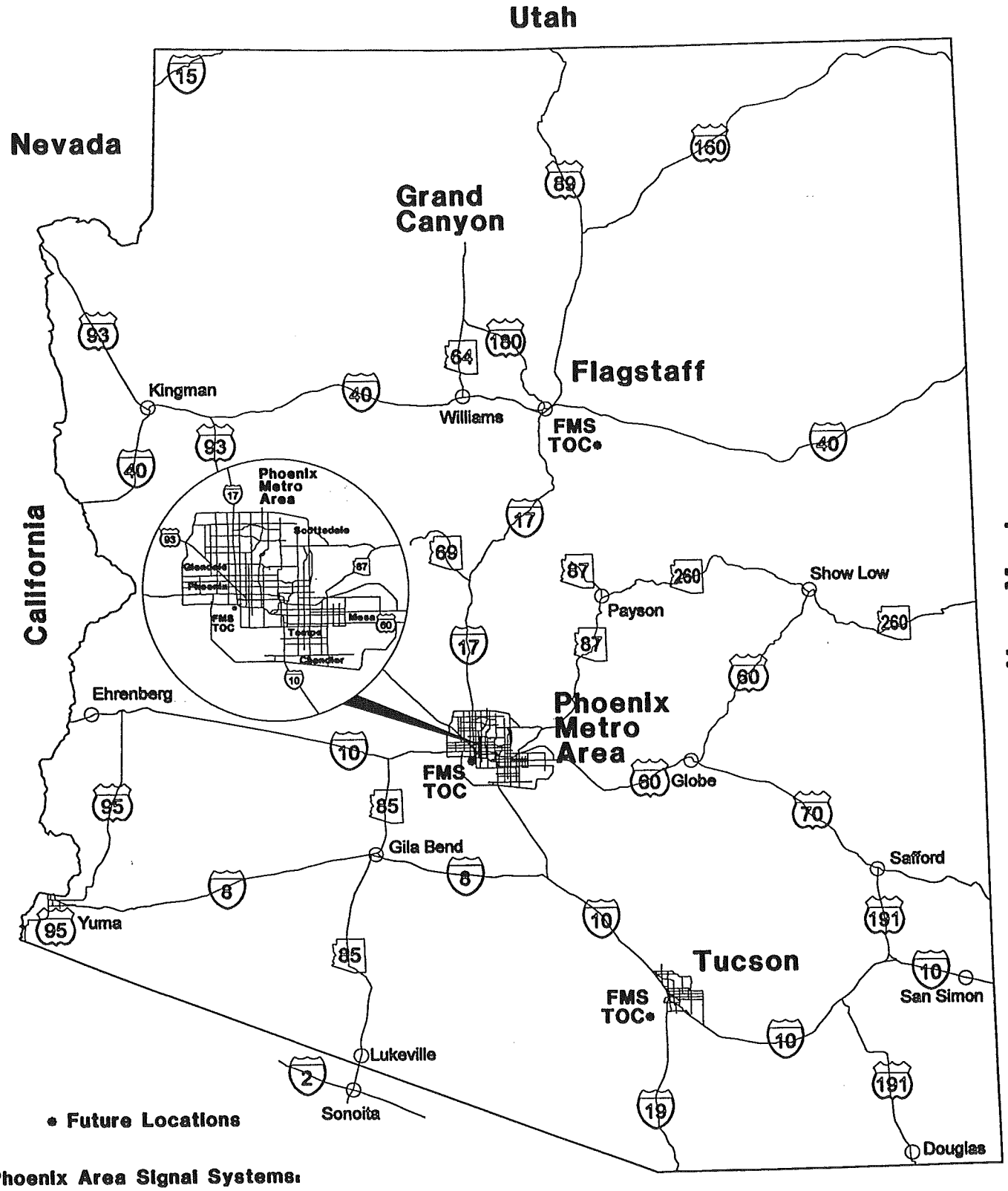
Table 3.2-1
Jurisdiction-owned Signal Systems (Coordinated)

Jurisdiction	Phoenix*	Scottsdale*	Tempe*	Mesa*	Glendale*	Chandler*	Tucson	Flagstaff	Maricopa County*
No. of Controllers	793	168	155	261	98	52	350	22	130
No. of Interconnected Controllers	481	150	148	247	6	43	350	5	0
Type of Controllers	NEMA Type 1	Model 170	NEMA Type 2	NEMA Type 1	NEMA Type 1	NEMA Type 1	NEMA Type 1 & 170	NEMA Type 1	NEMA Type 1
Applications Software	Computran UTCS	JHK 2000	Computran UTCS	SONEX	TRANSYT Closed Loop	Eagl- Marc Closed Loop	JHK 2000	Eagle Closed Loop	Closed Loop
Type of Communications	Telco	Telco	Telco	Telco	TWP	TWP	TWP & Telco	TWP & Microwave	TWP

*Phoenix Metropolitan Area

Table 3.2-2
State-owned Signal Systems

Jurisdiction	FMS	Maricopa County	Flagstaff
No. of Controllers	14	130	20
No. of Interconnected Controllers	14	19	20
Type of Controllers	Model 179	NEMA Type 1	NEMA Type 1
Applications Software	KHA	Econolite / Eagle	Econolite
Type of Communications	TWP / F-0	TWP / Telco	TWP



Map of Locations of Arizona Signal Systems

Figure 3.2–1

The long range ADOT communications infrastructure plan should include strategies for enhancing these systems so that they can be integrated into a statewide integrated ITS system. In many cases, these signal systems control arterials adjacent to freeways and are an important resource for effective integrated ATMS operations.

3.3 WIM/AVC

A number of Weigh-in-Motion (WIM) and Automated Vehicle Classification (AVC) sites have been installed in Arizona in connection with the HELP/Crescent project and pavement test sites of the Strategic Highway Research Program (SHRP).

There are six such WIM/AVC sites, installed as part of the HELP/Crescent project. They are listed in **Table 3.3-1** and shown in **Figure 3.3-1**. These stations have an integrated computer that collects raw data and creates statistics on operations.

All SHRP stations are operated and maintained by ADOT's Research Center. Periodically, traffic data are gathered from these sites via telephone-modem link. The locations of these stations are listed in **Table 3.3-2** and depicted on the map in **Figure 3.3-1**.

Table 3.3-1

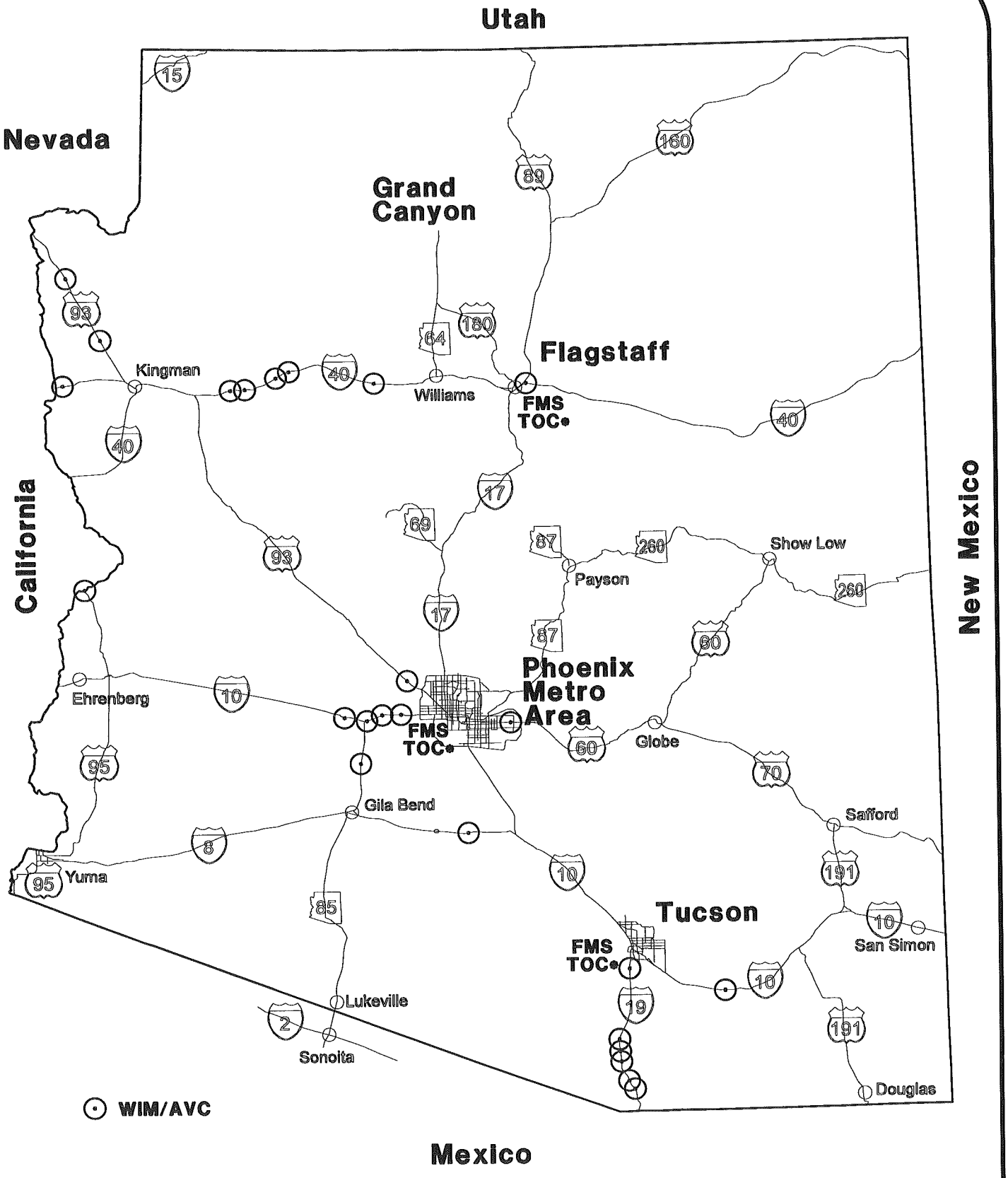
HELP WIM/AVC

1.	Ehrenberg Port of Entry	-	Milepost 4.0
2.	San Simon Port of Entry	-	Milepost 391.1
3.	Marana	-	Milepost 237.2
4.	Phoenix	-	Milepost 154.1
5.	Tonopah	-	Milepost 94.7 (partially operational)
6.	Benson	-	Milepost 300.1 (partially operational)

3.4 AUTOMATIC TRAFFIC RECORDER (ATR)

ADOT's Transportation Planning Division has a network of Automated Traffic Recorders (ATR) installed or proposed at approximately 31 sites. The purpose of these sites is to:

- Count vehicle traffic.
- Classify vehicles.
- Determine vehicle speed (at selected sites).



Locations of ATRC WIM/AVC Sites

Figure 3.3–1

Table 3.3-2

SHRP WIM/AVC Sites Operated by ATRC

AZ site #	SHRP ID	Location	Remarks
26	XX	I-10 MP 108 EB	
12	1006	I-10 MP 110.7 WB	
11	1007	I-10 MP 115.4 WB	
23	1001	I-10 MP 123.4 WB	
22	7614	I-10 MP 130.4 WB	
02	6053	I-10 MP 292.9 EB	
06	6060	I-19 KM 23.9 NB	
05	1015	I-19 KM 29.6 SB	
04	1016	I-19 KM 38 SB	
07	1017	I-19 KM 54.7 NB	
03	1018	I-19 KM 58.8 SB	
08	6054	I-19 KM 84.3 SB	
202	0600	I-40 MP 202 EB	
204	0600	I-40 MP 202 WB	
18	1024	I-40 MP 106.8 EB	
19	1025	I-40 MP 113.2 WB	
20	1002	I-40 MP 145.5 WB	
16	1062	I-40 MP 92.9 WB	
17	1065	I-40 MP 998.1 EB	
09	5000	I-8 MP 159.5 EB	
21	7079	SR-417 (LP 101) MP 11 NB	
15	1037	SR-68 MP 1.3 EB	
10	6055	SR-85 MP 141.9 SB	
13	1034	SR-95 MP 145.1 SB	
01	7613	US-60 MP 179 WB	
25	0100	US-93 MP 52.7 NB	
14	1036	US-93 MP 26.5 NB	

Figure 3.4-1 is a map showing the locations of these sites and **Table 3.4-1** lists these locations.

3.5 CALL BOXES

ADOT has installed 12 Emergency Phone Call Boxes using cellular telephones along I-19 on the route between Tucson and Green Valley. The purpose of these call boxes is to aid motorists in emergency situations. When employed, the cellular calls are directed to the Department of Public Safety. The locations of these call box sites are depicted in **Figure 3.5-1**.

3.6 SCAN® SITES (WEATHER DATA)

ADOT has installed 7 remote, computer-based, weather stations along I-40 in northern Arizona depicted in **Figure 3.6-1**. These weather stations collect data on:

- Temperature.
- Dew point.
- Wind speed and direction.
- Precipitation.
- Visibility.
- Road freeze point.
- Road temperature.
- Chemical content of moisture on roadway.

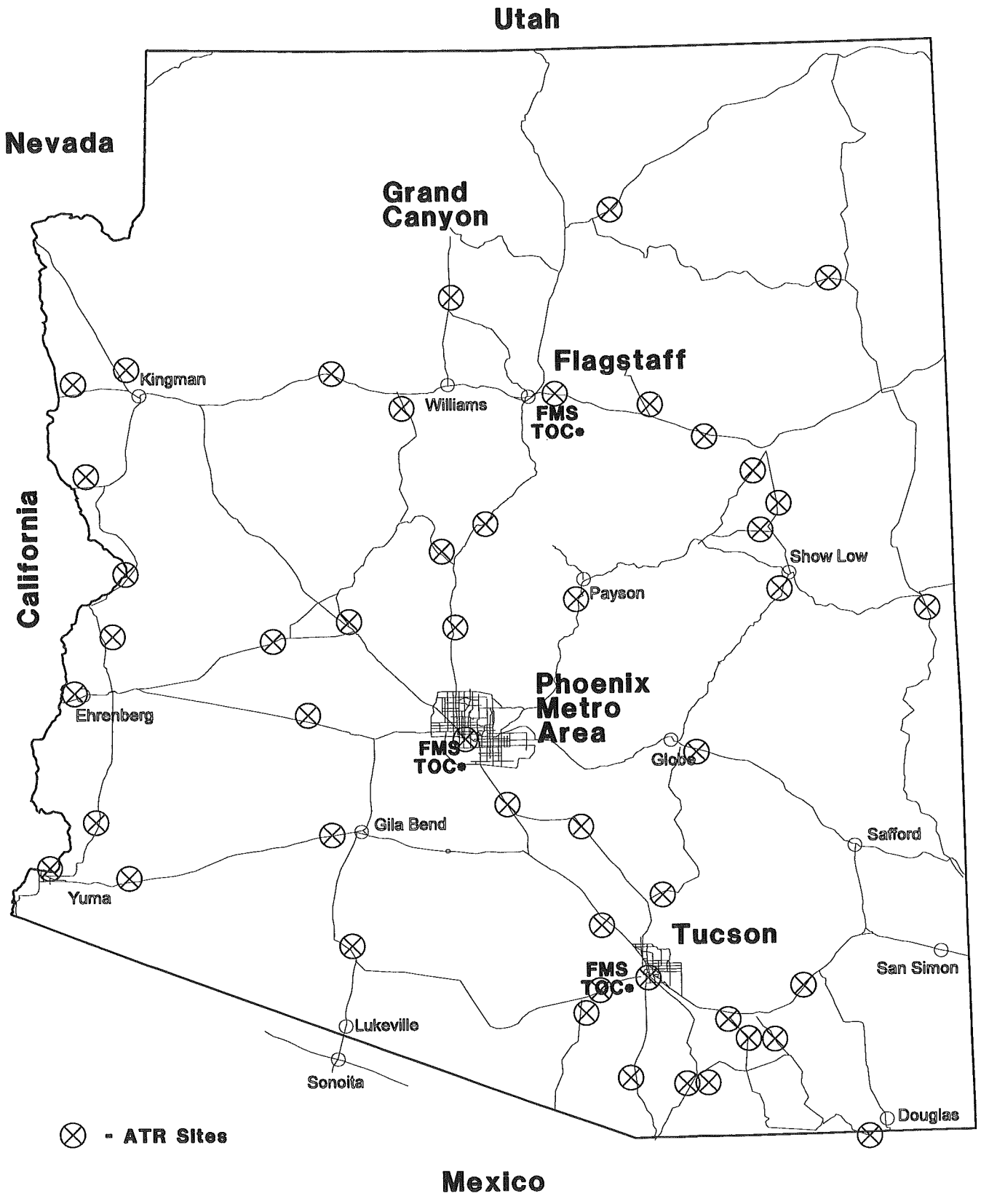
Locations along this route are subject to low visibility due to fog, rain, or snow; and to ice/snow conditions.

This data is communicated from the remote sensors via radio to a nearby microwave tower then into ADOT's microwave system and ultimately to ADOT offices in Flagstaff and Prescott. This information is currently used by maintenance personnel to assist in snow removal; however, the same information could be used to advise motorists of roadway conditions.

3.7 ELK CROSSING SIGNS

Variable Message Signs (VMS) are located on some routes where elk crossings occur to alert motorists during times of potential high crossing activity and for other conditions such as ice, fog, etc. These signs are located along State Route 260 northeast of Phoenix.

These are controlled from the ADOT TOC in Phoenix via dial-up telephone lines using modems. The locations of these signs are depicted on the map in **Figure 3.7-1**.



Proposed ATR Sites

Figure 3.4–1

Table 3.4-1

Proposed ATR Station Sites Classification
Leg Number by Station Number

Leg Number	Station Number	Location	Route
1	1	Thomas Road	SL 303
2	7	Flagstaff	I-40
3-4	15	Flagstaff	SR 89A
5-6-7-8	8	Phoenix	
9-10-11	20	Apache Jct.	US 60
12-13-14	22	Globe	US 70
15-16-17	34A	Gila Bend	I-8, B-8
18	251	McClintock	US 60
19-20-21-22	253	Quartzite	I-10, US 95
23-24-25	254	Wickenberg	SR 89, US 93
26-27-28	257	Topock	I-10, ST 95
29-30-31-126	259	Kingman	I-40, SR 66
32-33-34	260	Ashfork	I-40, SR 89
35-36-37	265	Show Low	US 60, SR 77
38-39-40	267	Prescottt	US 89, SR 69
41-42-43	270	Yuma	I-8, US 80
44	276	Nogales	SR 82-89
45-46-47	278	Mt. View	I-10, SR 83
48-49-50	281	Willcox	I-10, SR 191
51	287	Littlefield	I-15, MP 9.8
52-53-54	289	Kingman	US 93, SR 68
55-56-57	290	Cordes Jct.	I-17, SR 69
58	301	Yuma	US 95, Co. 14

Table 3.4-1 (cont'd)

Proposed ATR Station Sites Classification
Leg Number by Station Number

Leg Number	Station Number	Location	Route
59-60-61	302	Ajo	SR 85, SR 86
62-63-64	303	Toltec	I-8, I-10
65-66-67-68	304	Casa Grande	SR 84-287-387
69-70-71-72-73	305	Casa Grande	I-10, SR 187-387
74	306	Tucson	I-10
75-76-77	307	Tucson (S)	I-19, B19
78-79-80	308	Pearce (E)	SR 181, US 191
81-82-83	309	Winkelman	SR 77, SR 177
84-85-86	310	Eagar	SR 260, SS 260
87-88-89	311	Heber	SR 277, SS 260
90-91-125	312	Winslow	SR 87, SR 99
92-93-94	313	Holbrook	I-40, SR 77
95-96-97	314	Keam's Canyon	SR 264-87
98-99-100	315	Kayenta	US 160-163
101-102-103	316	Tuba City	US 160, SR 264
104-105-106	317	Cameron	US 89, SR 64
107-108-109	318	Flagstaff	B-40, US 180
110-111-112	319	Bitter Springs	US 89-89A
113-114-115	320	Valle	SR 64, US 180
116-117-118	321	Jacob Lake	US 89A, SR 67
119-120-121	322	Davis Dam	SR 68-95

Table 3.4-1 (cont'd)

Proposed ATR Station Sites Classification
Leg Number by Station Number

Leg Number	Station Number	Location	Route
122-123-124	323	Ganado	SR 264-191
127-128-129		Buckeye	SR 85
130		99th Avenue	SR74
131		San Luis	SR 95
201-202		Nogales	SR 189

3.8 ARIZONA PORTS OF ENTRY

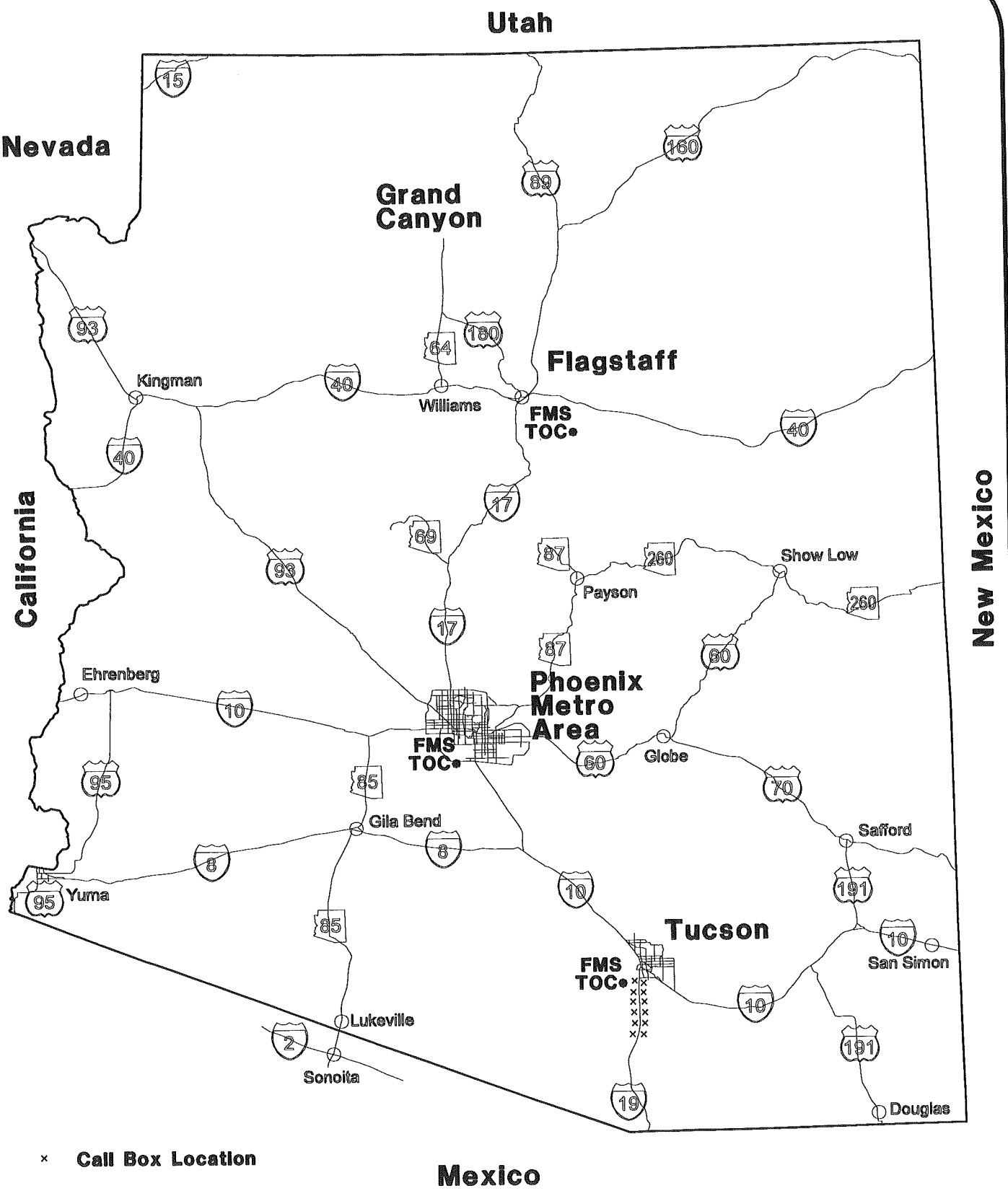
Arizona has 17 Ports of Entry on the California, Nevada, Utah, New Mexico, and (International) Mexico borders. The Ports of Entry are listed in **Table 3.8-1**. These ports are manned and operated by ADOT

3.9 RADIO BROADCAST DATA SYSTEMS (RBDS)

ADOT has a Memorandum of Agreement (MOA) with several public/private partners for an Advanced Travelers Information System (ATIS) demonstration project in the Phoenix metropolitan area that will employ RBDS.

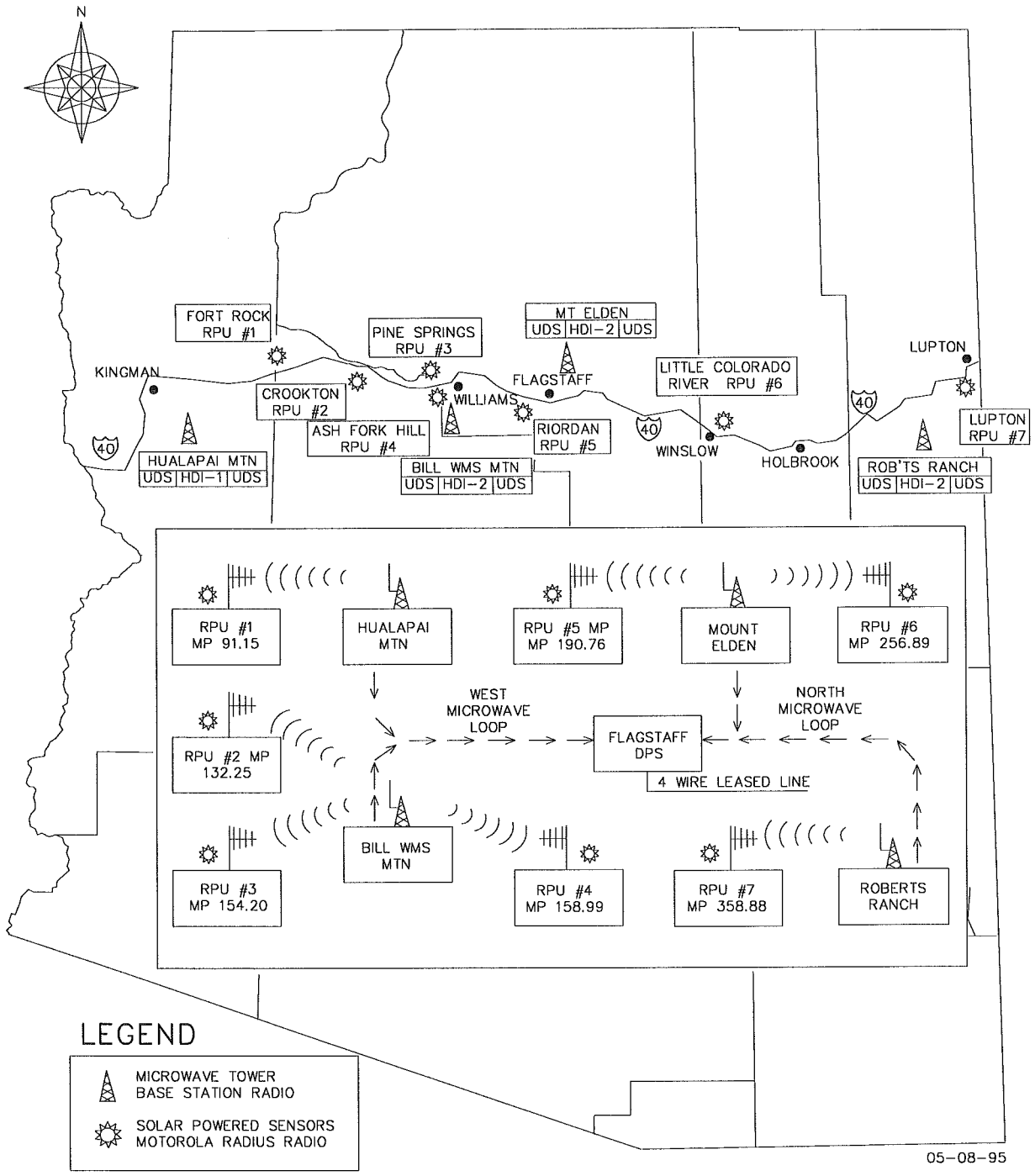
RBDS operates as a subcarrier over existing FM radio stations. FM radio stations operate in the 88-108 MHz band on channel spacings of 200 kHz. This spacing provides bandwidths greater than required for high quality stereo audio. Thus, portions of this bandwidth (see **Figure 3.9-1**) can be allocated for digital data transmission with wide-area coverage essentially the same as the FM audio coverage area. In fact, standard radio receivers can be equipped with an RBDS interface or an integrated RBDS data decoder.

This demonstration project has selected Scottsdale radio station KSLX FM (100.7 MHz), which has its antenna located on South Mountain, and is a 100-kilowatt station with a 50-mile radius coverage area.



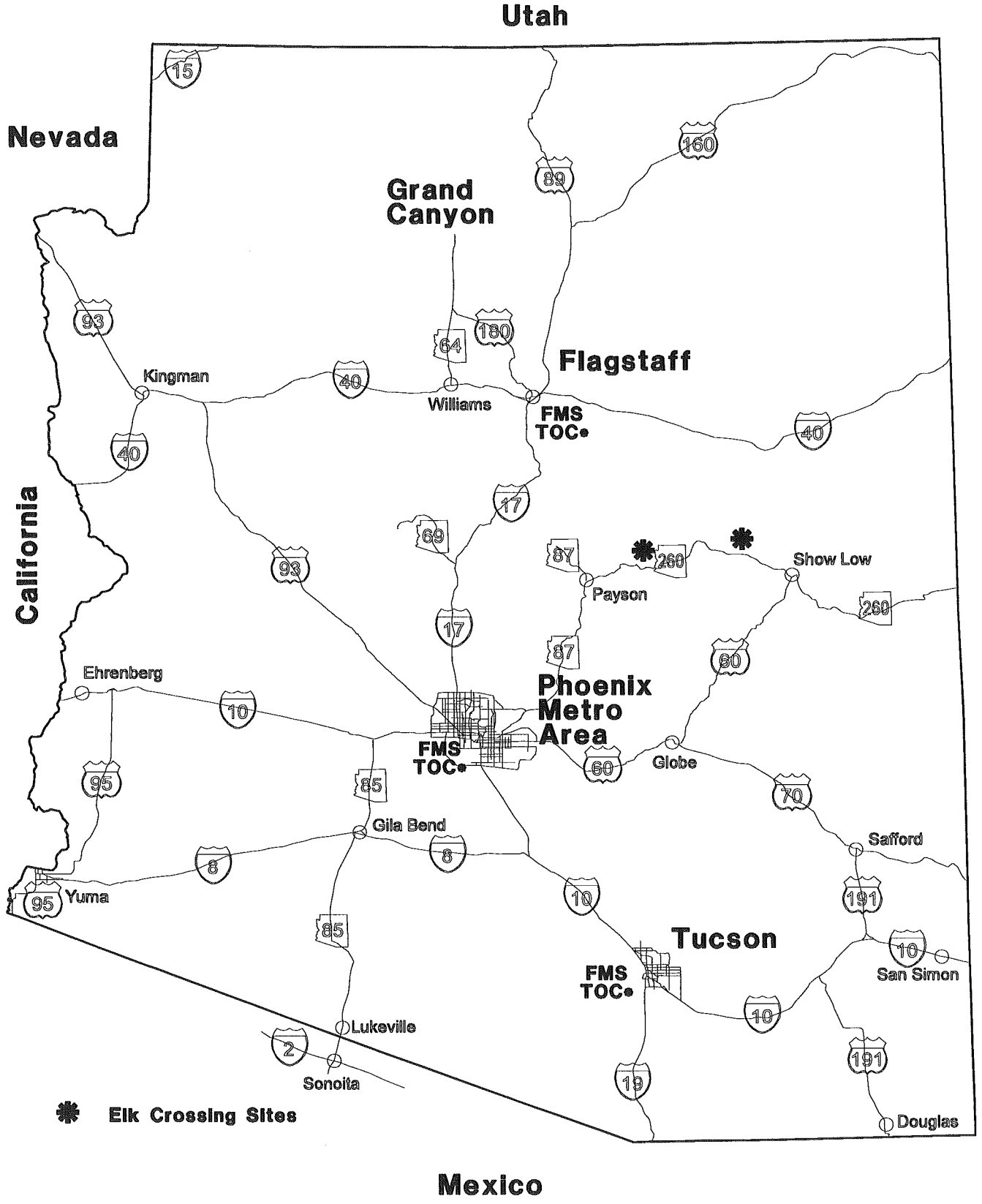
Call Box Locations

Figure 3.5–1



ADOT Districts Kingman, Flagstaff, and Holbrook Ice Warning System

Figure 3.6-1



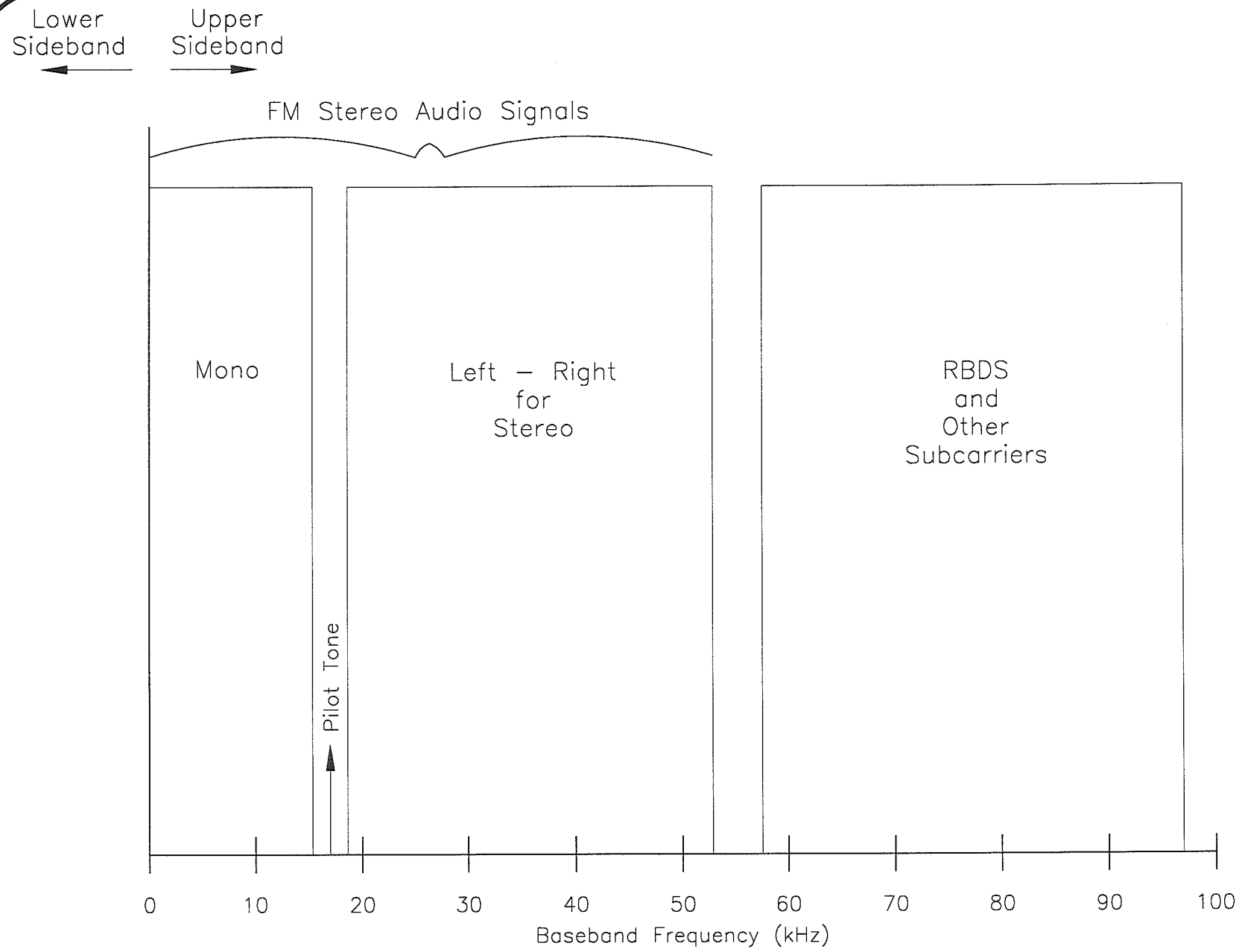
Locations of Elk Crossing Signs

Figure 3.7–1

Table 3.8-1

Arizona Ports of Entry

ADOT Org.	Location	Address	Phone #
2166	Douglas (S)	P.O. Box 875 Douglas 85608-0875	364-5011
2163	Duncan (S)	P.O. Box 175 Duncan 85534-0175	359-2562
2156	Ehrenberg (C)	P.O. Box 270 Ehrenberg 85334-0270	927-6652
2149	Fredonia (N)	P.O. Box 367 Fredonia 86022-0367	643-7096
2152	Kingman (C)	P.O. Box 549 Kingman 86402-0549	753-1465
2165	Nogales (S)	P.O. Box 1827 Nogales 85621-1827	287-3861
2148	Page (N)	P.O. Box 1807 Page 86040-1807	645-3269
2153	Parker (C)	310 California Avenue Parker 85344-4477	669-2534
2145	St. George (N)	P.O. Box 956 St. George UT 84770	801/673-3786
2142	Sanders (N) MP 340, I-40	P.O. Box 99 Sanders 86512-0099	688-2579
2161	San Luis (S) MP 01, SR 95	P.O. Box 449 San Luis 85349-0415	627-2970
2162	San Simon (S)MP 383.3, I-10	P.O. Box 68 San Simon 85632-0068	845-2280
2147	Springerville (N) P.O.E. & D/L	P.O. Box 209 Springerville 85938-0209	333-4415
2141	Teec Nos Pos (N)	P.O. Box 267 Teec Nos Pos 86514-0267	656-3214
2154	Topock (C) MP 3, I-40	P.O. Box 549 Kingman 86402-549	768-3756
2143	Window Rock (N)	Box 148 Window Rock 86515-0148	871-4274
2169	Yuma (S)	P.O. Box 5733 Yuma 85366-5733	783-5141



Baseband FM Spectrum Illustrating RBDS Subcarrier

Figure 3.9–1

The purpose of the demonstration project is to test equipment and concepts for wide-area ATIS that will provide travelers with accurate real-time information that will permit them to make more informed transportation decisions. This real-time information could include the following:

- Weather conditions.
- Known congestion based on FMS surveillance data and other sources.
- Known incident locations.
- Recommended routes.
- Others to be determined.

This information will be coded in International Traveler Information Interchange Standards (ITIS), which is a standard protocol for coding location and traveler-related events. The information may be shown in graphics on an in-vehicle navigation system, or in text on a small LCD display, or maybe broadcast as an audio message, depending on the type of receiver. Receivers may be in vehicles or at fixed locations.

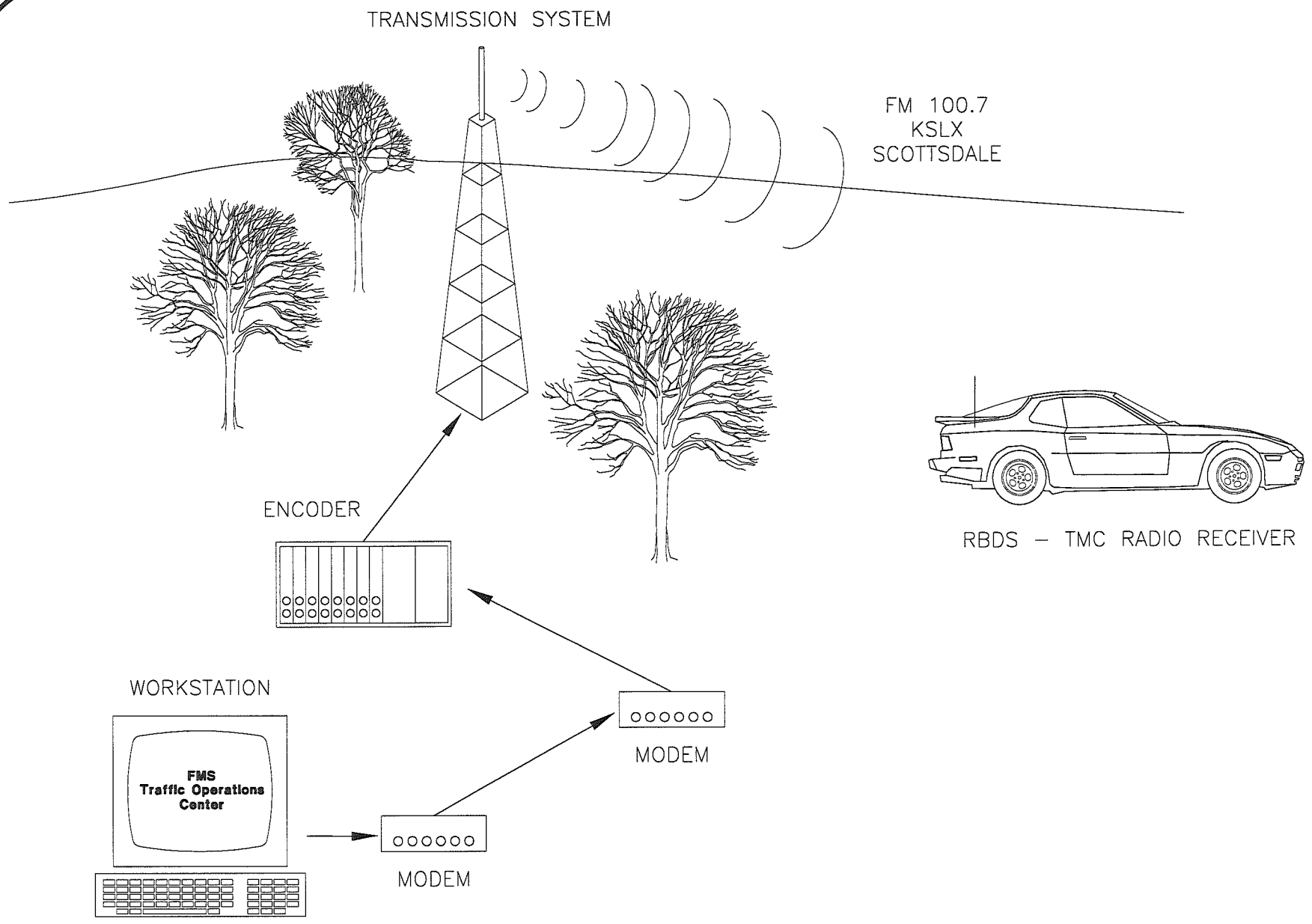
A block diagram of the anticipated demonstration system is presented in **Figure 3.9-2**.

3.10 EXPEDITED PROCESSING AT INTERNATIONAL CROSSINGS (EPIC)

A Field Operational Test (FOT) on Expedited Processing at International Crossings (EPIC) is planned at crossings in Nogales, Arizona. The FOT is sponsored by ADOT, FHWA, and private sector partners led by Lockheed IMS.

The goals of EPIC have been defined in meetings that involved Nogales businesses, trucking industry representatives, and Mexico's local and national officials. The goals are to expedite commercial vehicle travel across the border while maintaining/enhancing U.S. safety and regulatory requirements.

EPIC will use various "smart highway" technologies such as Automated Vehicle Identification (AVI) through transponders and readers, Weigh-in-Motion (WIM), Traffic Management Systems (TMS), License Plate Recognition (LPR), and digital photography to reach its goals. The project team consists of U.S. Customs, INS, USDA, FDA, and other related parties such as ADUANAS, SCT, brokers, shippers, truckers, and other private partners.



Block Diagram of RBDS System Demonstration Project

Figure 3.9–2

4.0 PLANNED ITS SERVICES

On-going plans and programs for delivering future ITS services in Arizona include:

- FMS expansion in the Phoenix Metro area.
- FMS for Tucson area.
- Flagstaff TOC.
- MAGIC/Maricopa County.
- Statewide VMS/RWIS programs.

4.1 PIMA COUNTY/TUCSON AREA FMS

The Pima Association of Governments has commissioned and completed a study for an FMS system along I-10 and I-19 to equip approximately 30 miles of highway in the Tucson area. Plans for implementation are on going in conjunction with current and planned freeway reconstruction.

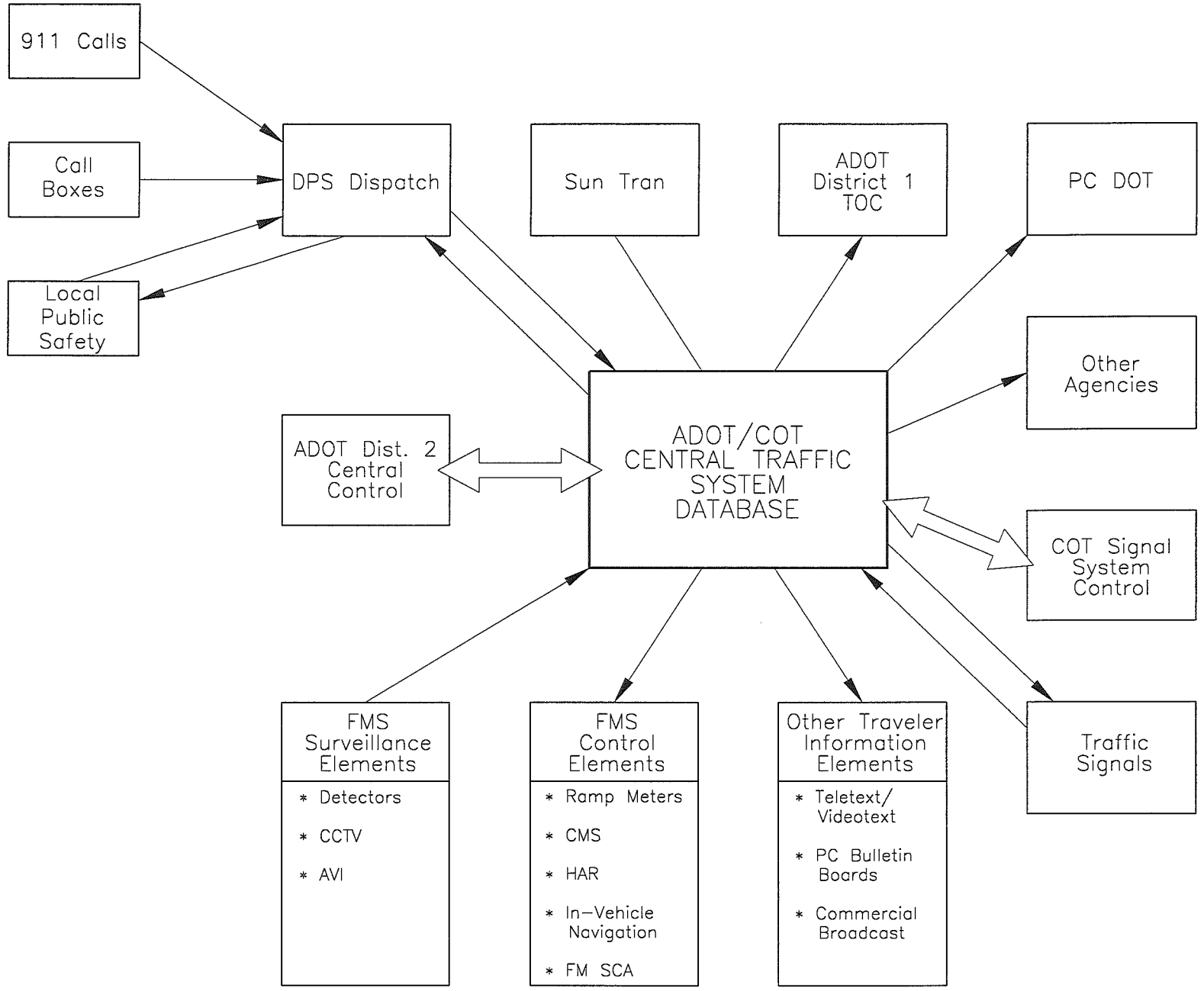
Included in this planning process are needed modifications to the existing freeway management organizational structure. The general functions identified for inclusion in the PAG/ADOT FMS include:

- Congestion Management.
- Incident Management.
- Traveler Information (ATIS).
- Commercial Vehicle Operations (CVO).
- Ancillary Functions.

All of the above functions require installation of various equipment along the freeway to monitor the status, provide control, inform travelers, collect statistical data, etc. A communications infrastructure is required to interconnect the various sources and sinks (destinations) of data. The Pima FMS plans identify the following for implementation to provide the above services:

- Ramp metering.
- Vehicle detectors (volume, speed, occupancy, and vehicle classification).
- CCTV cameras (general surveillance and incident detectors).
- Traveler information (HAR, commercial TV and radio broadcast, call-in service, VMS, etc.).

The proposed FMS organizational structure to implement these capabilities is presented in **Figure 4.1-1**.



Proposed PAG/ADOT FMS Organizational Structure

Figure 4.1-1

4.2 FLAGSTAFF FMS

Flagstaff is at the center of the I-40 corridor that stretches from the New Mexico border on the east and the California border on the west. This corridor covers approximately 359 miles and is characterized by:

- Significant CVO traffic.
- Significant weather-related problems in the winter.
- Historical/tourist attractions including Grand Canyon National Park, Painted Desert, Petrified Forest National Park, Walnut Canyon National Mounment, etc.
- Alignment with historical Route 66.
- Junction with I-17 and US 89 and US 180.

Nationally, this corridor is recognized as an excellent trailblazer and test bed for rural ATIS with Flagstaff serving as the TOC location.

The entire corridor is managed by three (3) ADOT District Offices in Kingman, Flagstaff, and Holbrook. Other important facilities along the interstate corridor include:

- Rest areas (3 eastbound, 4 westbound).
- Two ports of entry at the New Mexico and California borders to deal with permits and fees.

Of critical concern for the corridor is the level of safety. During winter, portions of the corridor are affected by snow, ice, wind, and high CVO traffic conditions. Fog can occur year round at certain locations as can smoke from controlled forest burns that restrict visibility. Commercial vehicle traffic constitutes 40% of the traffic. Seventy (70) to 80 percent of that is through traffic, creating long stretches of potentially unsafe continuous driving conditions.

The number of visitors to the state's tourist attractions is becoming significant enough to motivate discussions on vehicle restrictions in the Grand Canyon area and includes considerations of rural transit service.

Existing ITS-related systems include the previously discussed SCAN weather systems and WIM/AVC devices. The Flagstaff Chamber of Commerce installed an information system, named "Flagstaff Infoguide," to provide tourists with information on local attractions and events. This system has been decommissioned because the technology involved became outdated. The National Park Service and the National Forest Service have on-going efforts to implement a similar system. Longer range planning includes installation of Tourist Information Terminals at kiosks located in rest areas along I-40.

The corridor presents an excellent opportunity for integrated rural ITS as it involves multiple stakeholder agencies:

- Department of Public Safety.
- Governor's Office of Highway Safety.
- Metropolitan Planning Organizations and Councils of Governments.
- State Bureau of Tourism.
- Flagstaff Chamber of Commerce.
- National Park Service.
- National Forest Service.
- Navajo and Hopi Nations.
- Commercial Vehicle Operators.

A preliminary review indicates that most ITS services will be in bundles 1 and 5 (see **Table 2.1-1**) of the National ITS Program Plan and will provide significant information on rural ITS architecture requirements. The potential needs and solutions include:

- A system for dissemination of information on weather conditions
- Impaired visibility detection systems
- Use of closed circuit television cameras for security at rest areas
- A system for reporting maintenance and construction activities
- Development of a northern Arizona Traffic Operations Center (TOC).
- Identification of alternatives based on current and emerging technologies
- Improved operations at Ports of Entry
- Highway Advisory Radio (HAR) broadcasts.

4.3 MAGIC/MARICOPA COUNTY

Existing ITS-related programs have focused on individual ITS-related systems such as freeway management systems, signal systems, etc., often with minimal integration among these subsystems. The ITS vision requires that these services be integrated to promote efficient transportation management and traffic flow on freeways and adjacent arterial streets. A Maricopa Regional Information Center (MAGIC) program was initiated in 1993 involving 12 agencies and municipalities in the Maricopa/Phoenix area:

- City of Phoenix.
- City of Mesa.
- City of Tempe.
- City of Scottsdale.
- City of Glendale.
- City of Peoria.
- City of Chandler.

- City of Gilbert.
- City of Paradise Valley.
- Maricopa County.
- Regional Public Transportation Authority.
- ADOT.

The goal of MAGIC is to integrate the FMS system with signal systems of the individual municipalities. This integration must continue to support the local requirements of municipalities as well as provide expanded functionality to make regional travel more efficient. The program includes three concepts:

Phase 1	Signal Systems.
Phase 2	Advanced Traffic Management Systems (ATMS).
Phase 3	Advanced Traveler Information Systems (ATIS).

Recent work has resulted in a recommended communications architecture which will be discussed later in this document.

5.0 EXISTING COMMUNICATION INFRASTRUCTURE

Certain communication infrastructure facilities already exist within ADOT and long range plans should consider their utility. The following systems have been identified:

- ADOT, statewide WAN.
- ADOT, radio systems.
- FMS communication subsystem.

5.1 ADOT WAN NETWORK

ADOT has a Wide Area Network (WAN) that interconnects Local Area Networks (LANs) at various ADOT sites around the state. **Figure 5.1-1** presents a high level summary of the network. The network consists of bridges, routers, and the various local LAN networks. The network is interconnected by commercial DS-1 (1.544 Mbps) circuits and some private wire and fiber in the Phoenix area.

5.2 ADOT RADIO AND MICROWAVE SYSTEM

ADOT has three radio systems maintained by Arizona's Department of Public Safety (DPS) which provided information on the systems' capabilities.

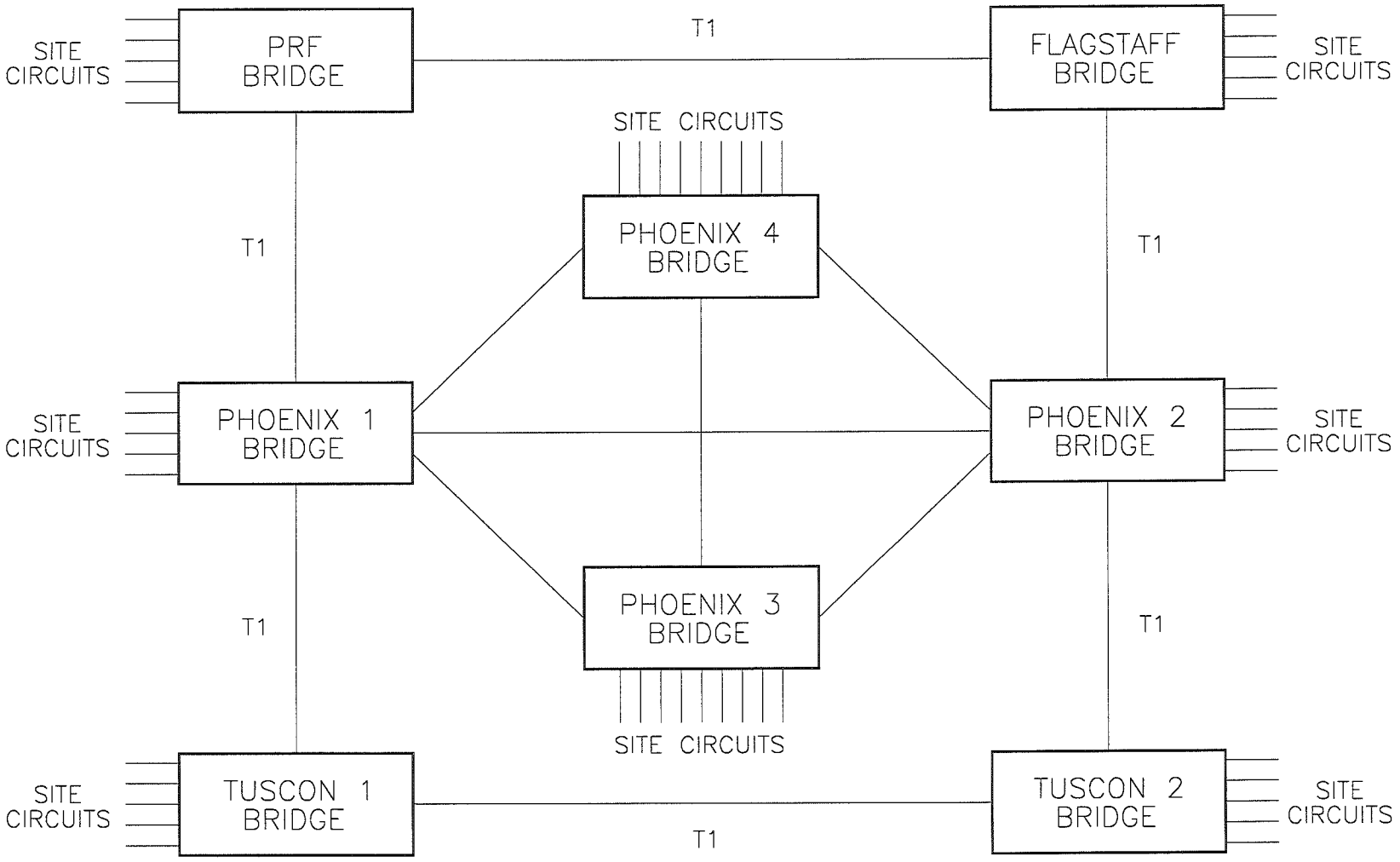
The first is a VHF Low Band Motor Vehicle Division (MVD) system consisting of:

- 14 Mountain top simplex base stations.
- Microwave interconnect from the base stations to MVD digital offices in Phoenix and Tucson.
- 15 Local base stations.
- 125 Mbile radios.

The system is approximately 15 years old. It does not use repeaters and is subject to cyclical skip interference. (**Figure 5.2-1** is a block diagram of the system.) MVD has plans to replace this system with a VHF high band system using a federal grant.

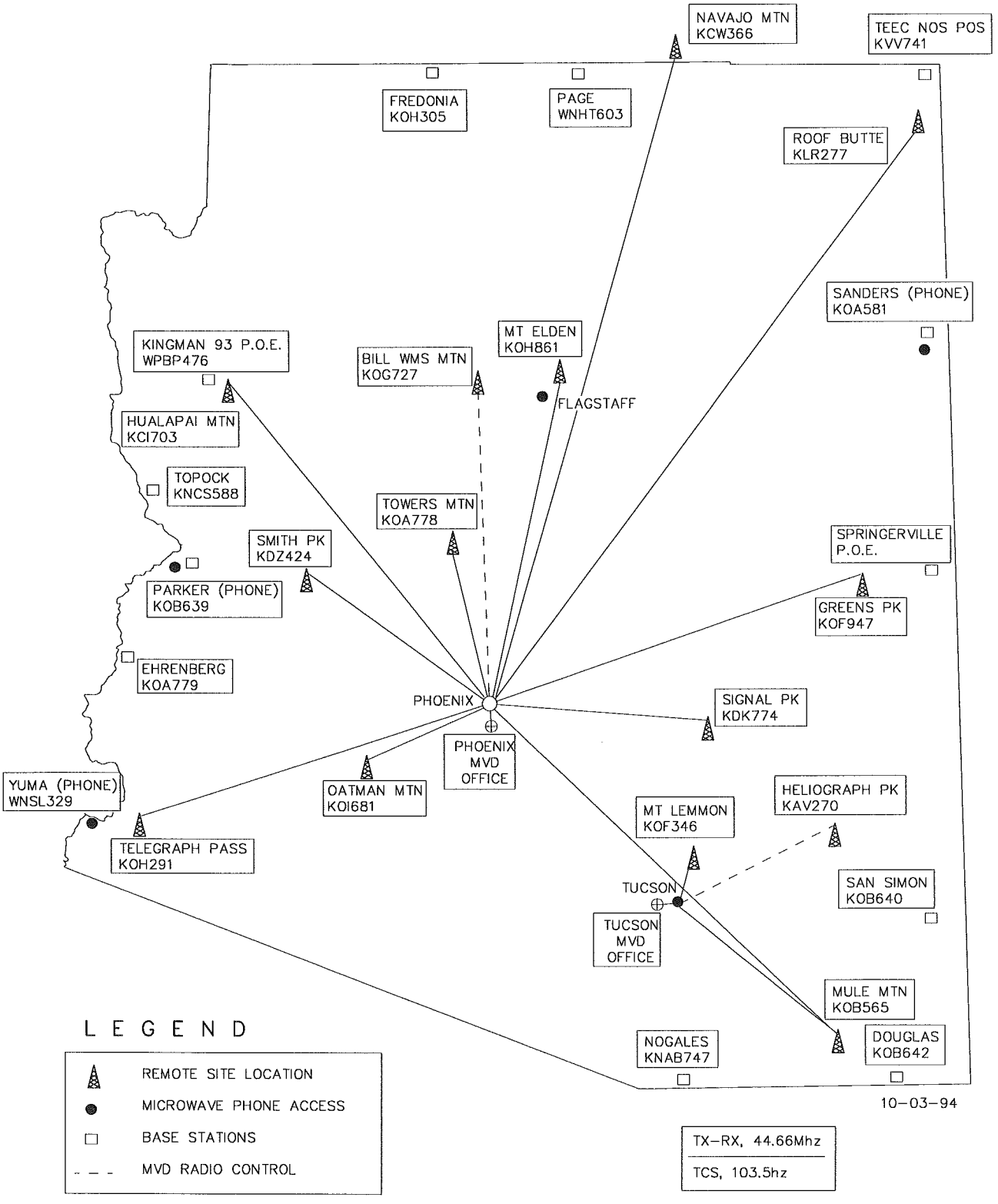
The second system is a statewide VHF High Band repeater network. This system consists of:

- 37 Repeaters, or 35 mountaintop sites, linked over the DPS analog microwave system.



ADOT WAN Network Summary Block Diagram

(Backbone Only)
Figure 5.1–1



MVD VHF Low Band Radio System

Figure 5.2-1

- Connections to district dispatch centers (except Phoenix) via ADOT/DPS microwave and wireline.
- VHF repeaters controlled by the FMS TOC in Phoenix via a digital microwave link to South Mountain.
- 1535 Mobile radios.
- 319 Portable radios.
- 149 Base stations.

The equipment is 10 to 15 years old and is being modified to a new ADOT maintenance district configuration. **Figure 5.2-2** is a block diagram of the systems.

The third system is an 8-channel, 800 MHz trunked simulcast system on three mountaintop sites in Maricopa County, as depicted in **Figure 5.2-3**. It uses ADOT's 10 GHz digital microwave system to link sites. Fifteen (15) talk groups are set up for District 1 construction and maintenance operations; four (4) talk groups are set up for MVD operations in Phoenix. The equipment includes:

- 24 Mountaintop base/mobile relay stations.
- 31 Base stations on 800 MHz.
- 438 Mobile radios.
- 112 Portable radios.

This system is three years old.

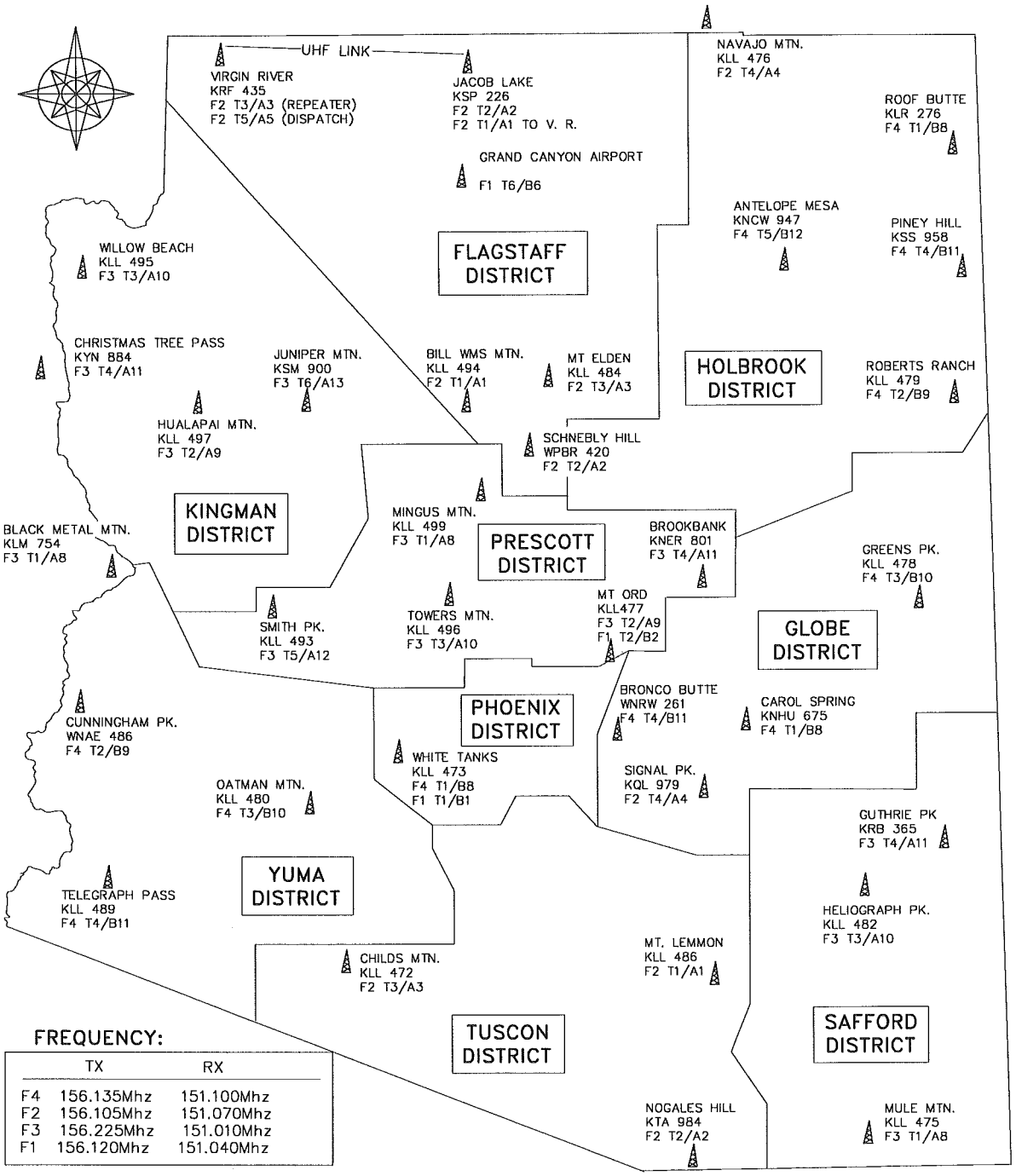
DPS operates several radio systems:

- Old statewide VHF channel maintained for outside agency interoperability.

- The Highway Patrol system on UHF 450/460 MHz consisting of 6-channel pairs reused over 11 districts, with 115 stations on 48 sites, plus a statewide channel.

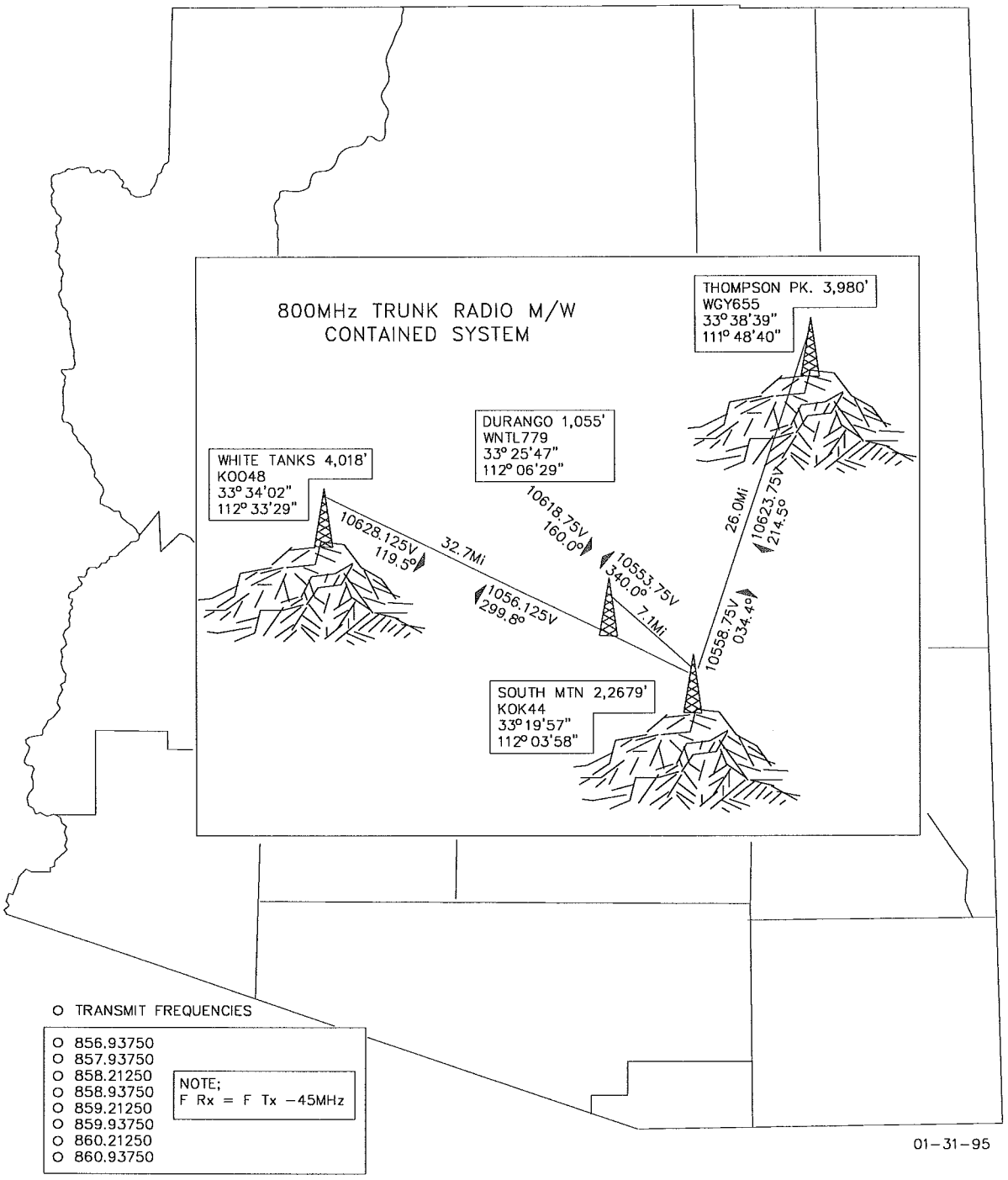
- Criminal Investigation operates a two (2) channel UHF system consisting of 21 stations at 17 sites statewide.

- The Telecommunications Division operates a UHF radio system used strictly for maintenance of the statewide microwave/radio network. It consists of 16 stations on 16 sites. An obsolete VHF "State" radio system still exists on 12 sites.



ADOT Radio System

Figure 5.2-2



ADOT 8-Channel Trunked Simulcast System

(MARICOPA COUNTY)

Figure 5.2-3

Other equipment consists of:

- Approximately 1500 mobile radios.
- 1250 Portable radios.
- Dispatch centers in Phoenix, Tucson, and Flagstaff.

None of the channels used by DPS are directly compatible with any ADOT radio system. Interconnection is possible only at dispatch centers through cross scanning or cross patching.

In response to the FCC's Refarming Report and Order (R&O), issued on June 15, 1995, DPS indicates that plans will be developed to upgrade these systems; however, the R&O does not require upgrades to the VHF low and 800 MHz bands.

5.3 PHOENIX FMS COMMUNICATION SUBSYSTEM

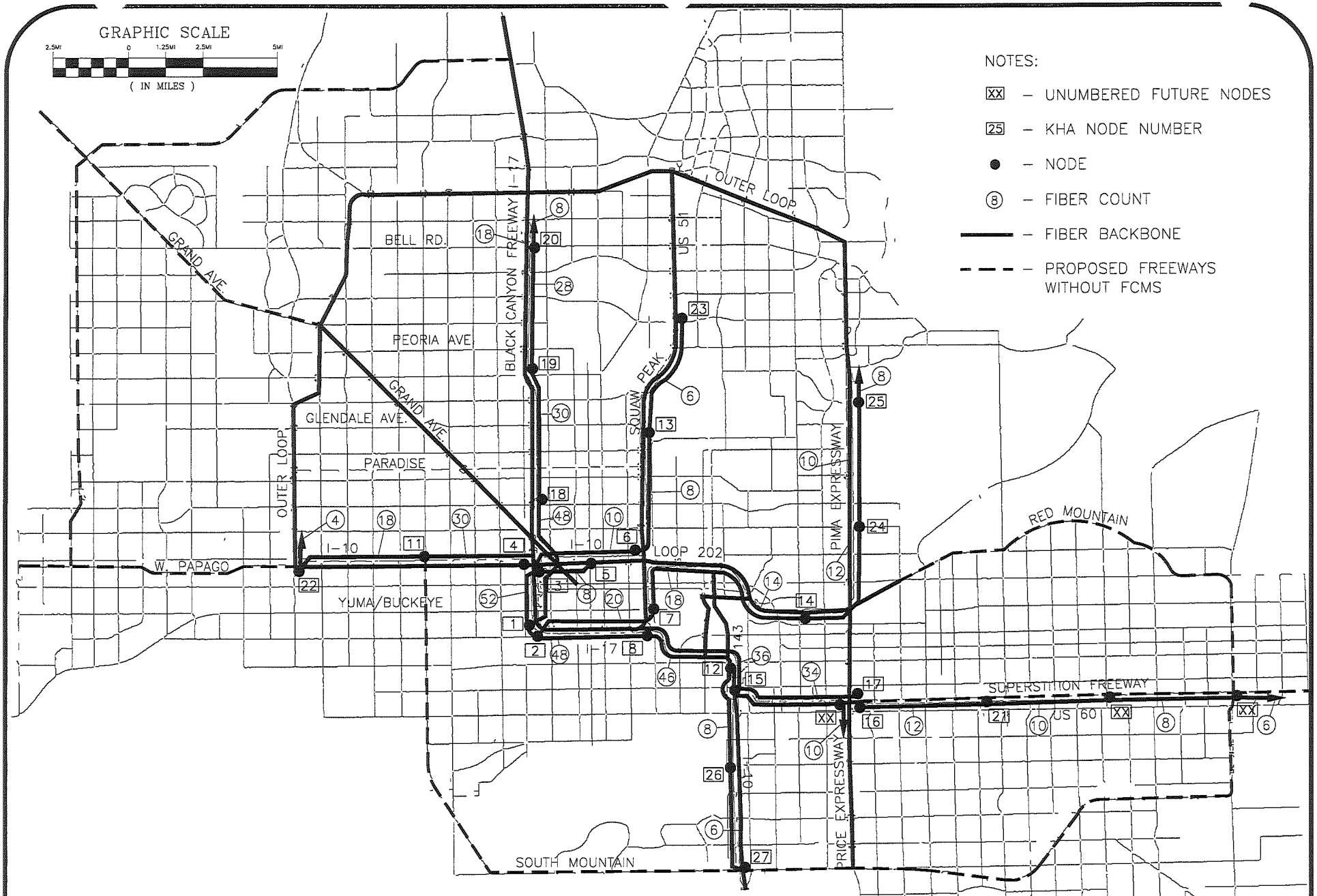
The Phoenix FMS has plans to instrument and equip over 200 miles of freeway in the Maricopa County/Phoenix area as depicted in **Figure 5.3-1**. This figure also depicts the current approximately 29 miles of instrumented and equipped freeway predominantly along I-10 and I-17. **Figure 5.3-2** illustrates how field equipment is connected to the TOC via the communications subsystem. In summary, the communications subsystem consists of:

- An SMFO fiber backbone from TOC to communications nodes located approximately every 5 miles.

- An overlay of fiber and twisted wire pair (TWP) local links from communications nodes to field equipment controller cabinets. The fiber links are for CCTV cameras located at approximately 1-mile intervals. The TWP links are for low-speed controller data using multidrop, 1200/2400 bps series 400 modems.

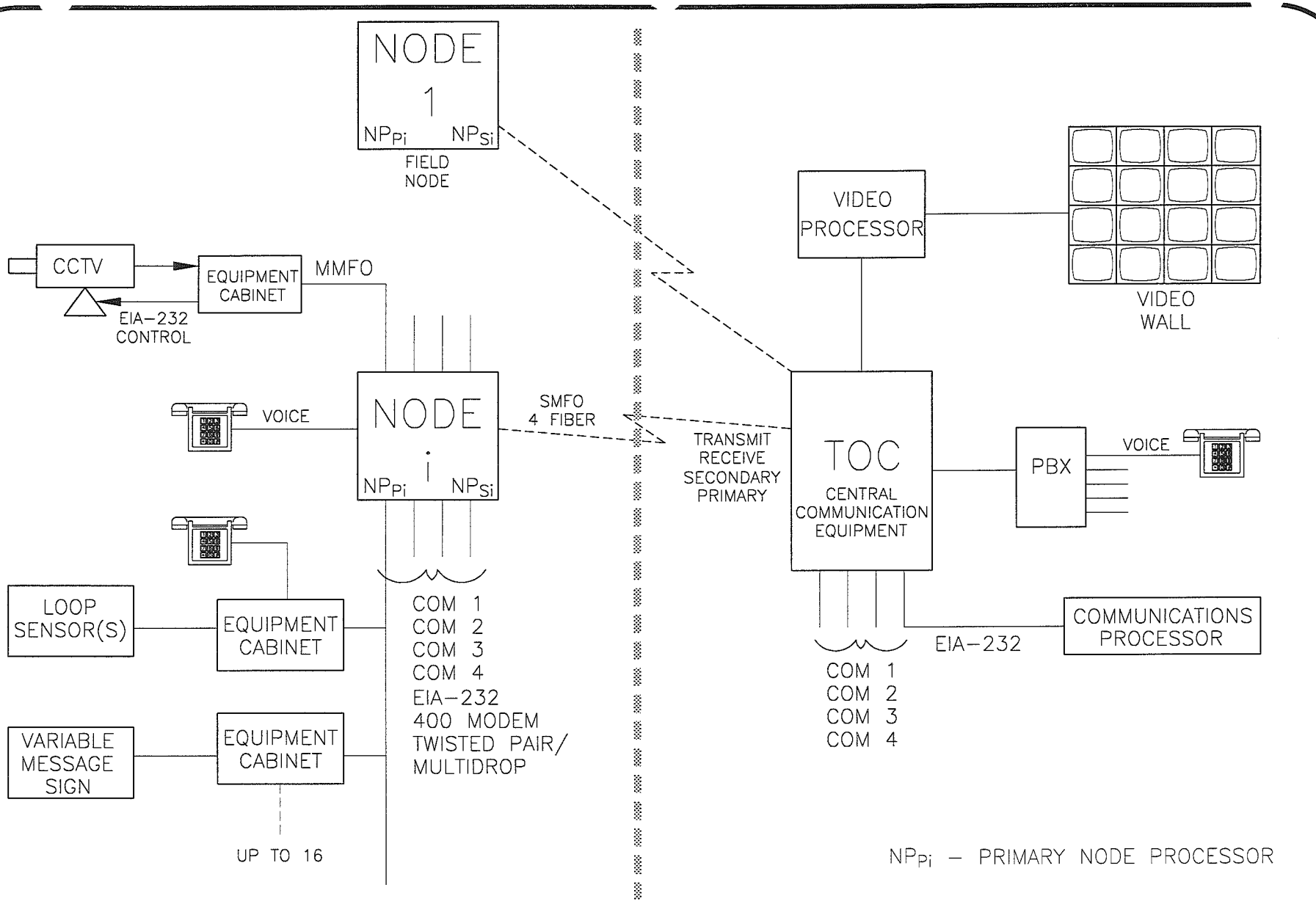
- The video and data are Frequency Division Multiplexed (FDM) at the communications nodes for communications to/from the TOC.

The FDM multiplexing is a proprietary technique that was typical of designs and products in the 1988-1992 time period of FMS design. Now, however, ITS is transitioning to open, non-proprietary standard designs. Fortunately, the expensive SMFO cable plant ***is*** suitable for the emerging open, standard designs.



FMS Communication System
29 Miles Implemented, Over 200 Miles Planned

Figure 5.3–1



Communication Subsystem Connection

Figure 5.3–2

5.4 COMMERCIAL SERVICES

There are many commercial service providers in the state of Arizona. In **Appendix A**, we have provided lists of:

- Cellular Service Providers.
- Commercial Telephone Service Providers.

5.4.1 ISDN

Integrated Services Digital Network (ISDN) is a digital dialup telephone service that was conceived to provide end-to-end digital telephone service. After years of hype and unrealized potential, ISDN appears to have achieved some recent successes largely as a result of demand for higher speed (compared to dialup modem) access to internet services. It is also widely used by the radio broadcast industry for higher quality voice transmission from remote sites (e.g., sports arena, etc.) and will offer similar benefits to ITS.

For years, the commercial telephone network has employed digital switching, multiplexing (i.e., T1 digital hierarchy), and transmission. However, the TWP connecting the Central Office (CO) switch to subscriber telephones has been analog as depicted in the lower part of **Figure 5.4.1-1**. ISDN essentially extends the digital DS-0 (or B channel in ISDN terminology) to the subscriber premise as depicted in the upper part of **Figure 5.4.1-1**.

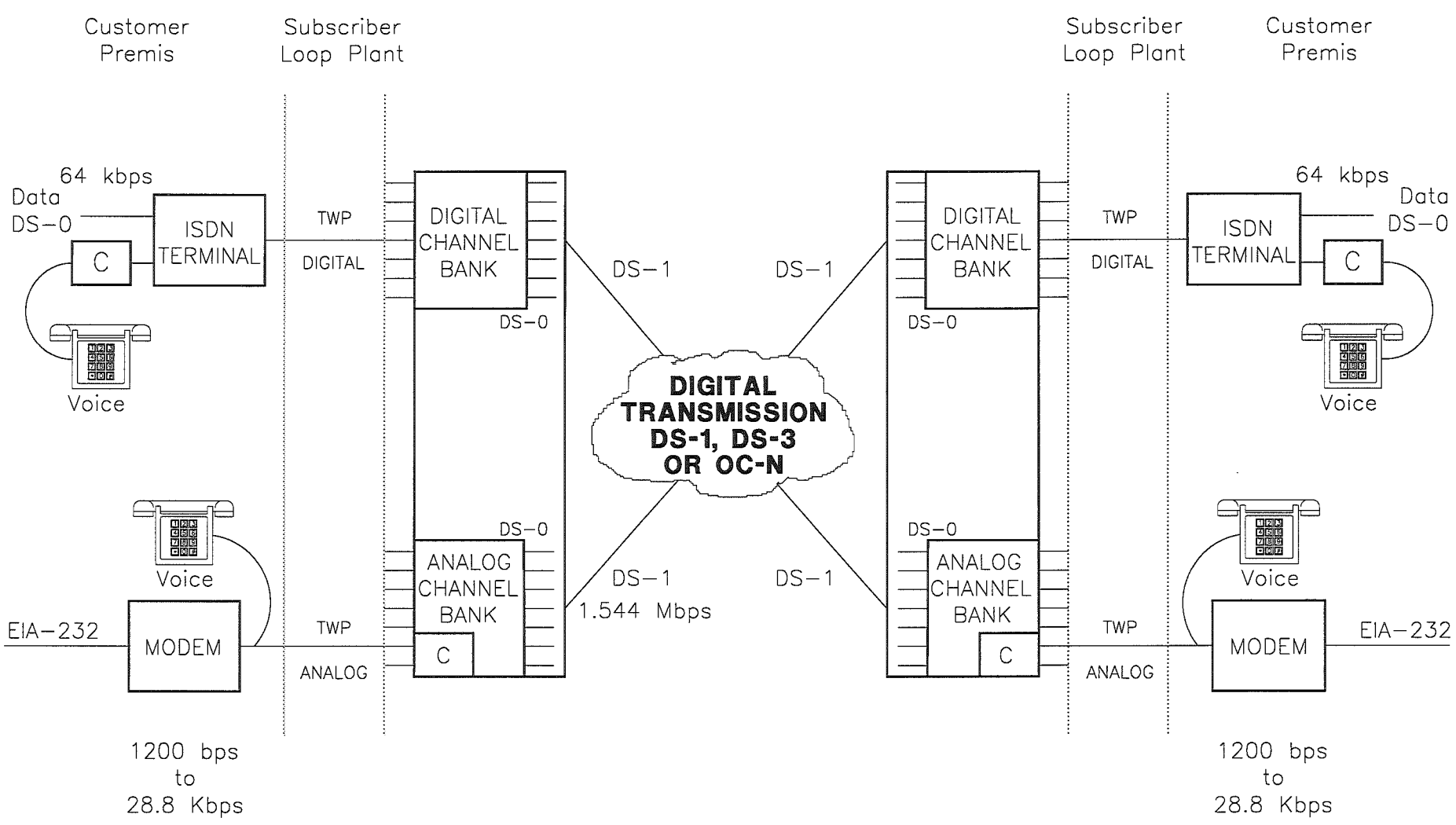
A D (or data) channel is also provided to serve the equivalent telephone signal/control functions such as on/off hook, DTMF dial tones, busy signal, etc., tones that are provided "in-band" on the standard analog telephone circuits. Additionally, this D channel may also serve as a packet data channel for packet services, although most current services appear to use B channels.

ISDN is basically a WAN service that is available in two forms:

- Basic Rate Interface (BRI).
- Primary Rate Interface (PRI).

BRI provides the following:

- 2 B Channels (DS-0, 64 kbps) for a total of 128 kbps.
- 1 D Channel at 16 kbps.
- Deployment over existing telephone company TWP loop plant by providing ISDN terminals at both the customer premises and the service CO (see **Figure 5.4.1-1**).



C – CODEC (ie, analog–digital conversion)

ISDN: End-to-End Digital Connectivity

Figure 5.4.1–1

PRI provides:

- Essentially DS-1 service at 1.544 Mbps.
- Up to 23 DS-0 channels available within the DS-1 frame, (although other rates can be supported).
- 1 D channel at the DS-0 rate of 64 kbps.
- This requires special 4-wire TWP circuits and repeaters for longer distances (the equivalent of T1 DS-1 circuit requirements).

Costs for ISDN circuits vary and can include (for BRI):

- Installation charges (0-$150).
- Per-month circuit charges ($20-$60).
- Per-minute usage charges (0 to $0.19 per minute).

Appendix A contains a list of U.S. West's Arizona ISDN BRI single line service availability by wire center.